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COMPUTER PROGRAM FOR ONE-DIMENSIONAL NONEQUILIBRIUM REACTING GAS FLOW

H. S. DRESSER, E. P. FRENCH, H. G. WEBB, JR.

SPACE DIVISION
NORTH AMERICAN AVIATION, INC.

TECHNICAL REPORT AFFDL-TR-67-75

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FOREWORD

This research program was initiated 3 October 1966 by the Electrogasdynamics Branch of the Flight Dynamics Laboratory, Directorate of Laboratories. The work was performed between 3 October 1966 and 31 March 1967 by the Space Division of North American Aviation, Inc., Downey, California. The Contract Number is F33 615 67 C 1058, BPSN: 7(61142612-62405334). Lt. Thomas E. Miller (FDME) was the Contract Monitor. The authors wish to express their appreciation to Lt. Miller for his encouraging aid during the program. The authors would also like to thank Mr. Ronald B. Anderson for his invaluable help in developing the computer program. This report is identified by Contractor's Control Number SID 67-364.

This technical report has been reviewed and approved.

Demetrius Zonars
for PHILIP P. ANTONATOS
Chief, Flight Mechanics Division
AF Flight Dynamics Laboratory

ABSTRACT

A computer program has been developed for one-dimensional nonequilibrium reacting gas flow. The program is written in Fortran IV and is compatible with the IBM 7044/7094 direct coupled digital computer system at Wright-Patterson Air Force Base, Ohio. In addition to nonequilibrium chemistry, the program includes nonequilibrium vibrational and electronic energy relaxation and coupling effects between these energy modes and the chemistry. The formulation is based on a one-dimensional flow matching either a prescribed pressure or area variation along a streamtube. Thermodynamic properties are computed by assuming an ideal gas mixture and the equilibration of translational and rotational temperatures. The internal energy modes, rotation, vibration, and electronic excitation, are considered uncoupled; and a rigid rotator, cut off simple harmonic oscillator, independent of the electronic state, is assumed. Excitation of vibrational and electronic energies are treated similarly with terms which account for relaxation and chemical reactions. The effects of nonequilibrium vibrational and electronic states on chemical rates are included in the coupling analysis. The vibrational relaxation time constants were obtained from the Millikan and White data while the electronic relaxation time constants were determined for nitrogen from an analysis of existing shock tube radiation measurements. The computer program was used to solve for the nonequilibrium flow in a hypersonic nozzle and for eight streamlines in the inviscid flow field over a spherically blunted nine-degree semiapex angle cone at zero angle of attack.

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LIST OF ABBREVIATIONS AND SYMBOLS

PHYSICAL SYMBOL	FORTRAN SYMBOL	DEFINITION	UNITS (cgs / U.S. / S.I)
A	A	Streamtube Area	cm^2 ft^2 m^2
b_e	BE	Exponent for Backward Electronic Coupling Factor	N.D.
b_v	BV	Exponent for Backward Vibrational Coupling Factor	N.D.
c_p	CP	Specific Heat at Constant Pressure	ergs/°K-g BTU/°R-lb joules/°K-kg
D, h_o	HOVRW	Dissociation Energy	ergs/g BTU/lb joules/kg
E_e	EE	Electronic Energy Lost Per Unit Mass of Mixture (Based on Electronic Temperature of N_2)	ergs/g_m BTU/lb_m joules/kg_m
$\bar{E}_e$	(NOT USED)	Electronic Energy Lost Per Unit Mass of Mixture (Based on Mean Temperature, Tf)	ergs/g_m BTU/lb_m joules/kg_m
E_L	EL	Spectroscopic Energy Levels	°K °R °K
E_v	EV	Vibrational Energy Lost Per Unit Mass of Mixture (Based on Temperature Tv)	ergs/g_m BTU/lb_m joules/kg_m
$\bar{E}_v$	EVBRIK	Vibrational Energy Lost Per Unit Mass of Mixture (Based on Temperature Tf)	ergs/g_m BTU/lb_m joules/kg_m
f_e	FE	Exponent for Forward Electronic Coupling Factor	N.D.
f_v	FV	Exponent for Forward Vibrational Coupling Factor	N.D.
g	G	Degeneracy	N.D.

PHYSICAL SYMBOL	FORTRAN SYMBOL	DEFINITION	UNITS
$\bar{G}_e$	(NOT USED)	Electronic Energy Gained Per Unit Mass of Mixture	ergs/g_m BTU/lb_m joules/kg_m
$\bar{G}_v$	GVBEIK	Vibrational Energy Gained Per Unit Mass of Mixture	ergs/g_m BTU/lb_m joules/kg_m
h	HSUM	Enthalpy Per Unit Mass of Mixture	ergs/g_m BTU/lb_m joules/kg_m
h	H	Enthalpy Per Unit Mass of Species	ergs/g_m BTU/lb_m joules/kg_m
K_b	BKTT	Backward Chemical Reaction Rate Based on Tt	$(cm^3/g\text{-mole})^{\Sigma\alpha}\left(\frac{1}{sec}\right)$ $(ft^3/lb\text{-mole})^{\Sigma\alpha}\left(\frac{1}{sec}\right)$ $(m^3/kg\text{-mole})^{\Sigma\alpha}\left(\frac{1}{sec}\right)$
K_f	FKTT	Forward Chemical Reaction Rate Based on Tt	$(cm^3/g\text{-mole})^{\Sigma\beta}\left(\frac{1}{sec}\right)$ $(ft^3/lb\text{-mole})^{\Sigma\beta}\left(\frac{1}{sec}\right)$ $(m^3/kg\text{-mole})^{\Sigma\beta}\left(\frac{1}{sec}\right)$
M	XMF	Mass Flow	g/sec lb/sec kg/sec
N	——	Total Particles/cc	——————
N_L	——	Particles/cc With Energy Level EL	——————
N	YN	Number of Vibrational Energy Levels	N.D.
N_1	NI	Total Number of Species (Including Inert Species)	N.D.
N_2	N2	Total Number of Reactions	N.D.
N_A	——	Avogadro's Number	$6.023\text{x}10^{23}$ molecules/g-mole $2.73\text{x}10^{26}$ molecules/lb-mole $6.023\text{x}10^{26}$ molecules/kg-mole

PHYSICAL SYMBOL	FORTRAN SYMBOL	DEFINITION		UNITS
m	XN	Species Mole/Mass of Mixture Ratio		g-mole/g_m lb/mole/lb_m kg-mole/kg_m
P	P	Pressure		dynes/cm^2 lb/ft^2 N/m^2
Q	----	Partition Function		N.D.
R	R	Universal Gas Constant	8.314×10^7 1544 8.314×10^3	ergs/°K-g-mole BTU/°R-lb-mole joules/°K-kg-mole
s	S	Streamtube Distance		cm ft m
t	----	Time		sec sec sec
T_e	TE	Electronic Temperature		°K °R °K
T_f	TFI	Effective Temperature		°K °R °K
T_r	----	Rotational Temperature		°K °R °K
T_t	TT	Translational Temperature		°K °R °K
T_v	TV	Vibrational Temperature		°K °R °K
u	U	Velocity		cm/sec ft/sec m/sec
U	UV	Parameter Characterizing Preferential Dissociation		°K °R °K
V_e	VE	Electronic Coupling Factor		N.D.
V_v	VV	Vibrational Coupling Factor		N.D.

PHYSICAL SYMBOL	FORTRAN SYMBOL	DEFINITION	UNITS
ω	W	Molecular Weight	g/g-mole lb/lb-mole kg/kg-mole
X	----	Mole Fraction	N.D.
α	ALFA	Forward Stoichiometric Coefficient	N.D.
β	BETA	Backward Stoichiometric Coefficient	N.D.
ϵ_e	HE	Electronic Energy Per Unit Mass of Species	ergs/g BTU/lb joules/kg
ϵ_v	HV	Vibrational Energy Per Unit Mass of Species	ergs/g BTU/lb joules/kg
θ	THETA	Vibrational Characteristic Temperature	°K °R °K
μ	YMU	Reduced Mass $= \dfrac{\omega_N \cdot \omega_M}{\omega_N + \omega_M}$	g/g-mole lb/lb-mole kg/kg-mole
τ_e	TAUE	Electronic Relaxation Time Constant	sec
τ_v	TAUV	Vibrational Relaxation Time Constant	sec
ν	----	Frequency	1/sec 1/sec 1/sec
ρ	RHO	Density	g/cm^3 lb/ft^3 kg/m^3

SUBSCRIPTS

PHYSICAL SYMBOL	FORTRAN SYMBOL	DEFINITION
b	----	Backward Reaction
el	----	Electron
eq	----	Equilibrium
f	----	Forward Reaction
i	I	Species i

PHYSICAL SYMBOL	FORTRAN SYMBOL	DEFINITION
j	J	Species j
k	K	Reaction k
ℓ	——	Electronic Energy Level
m	——	Mixture
M	——	Second Collision Partner
N	——	First Collision Partner
P	——	Peak Radiation
S	——	Shock
TOT	——	Total (Pressure)
∞	INF	Evaluated at Local Translational Temperature
1	——	Refers to Collisions With Neutral Particles
2	——	Refers to Collisions With Electrons

ADDITIONAL FORTRAN SYMBOLS

FORTRAN SYMBOL	DEFINITION
ALPHA	Summation of Forward Stoichiometric Coefficients for a Reaction
BBETA	Summation of Backward Stoichiometric Coefficients for a Reaction
BA	Constant, a, in Backward Chemical Rate Constant Expression
BB	Exponent, b, on Temperature Term for Backward Rate Constant
BC	Constant, c, in Exponential Term of Backward Rate Constant
CKAT	Indicator Used to Indicate Reactions Containing Catalytic Species
CØUNT	Counter for Increasing ICØUNT

FORTRAN SYMBOL	DEFINITION
DHE	Derivative of Electronic Energy (Per Mass of Species i)
DHV	Derivative of Vibrational Energy (Per Mass of Species k)
DPA	Derivative of Matching Parameter
DTE	Derivative of Electronic Temperature
DTV	Derivative of Vibrational Temperature
DTT	Derivative of Translational Temperature
DU	Derivative of Velocity
DXN	Derivative of Species Mole to Mass Ratio
EETT	Electronic Energy Based on Vibrational Temperature
ELVBR	Indicator Used to Set EVBRIK to Proper Value (ϵ_v, ϵ_{v_∞} or $\bar{\epsilon}_v$)
EPSE	Electronic Energy Per Unit Mass of Species i
EPSV	Vibrational Energy Per Unit Mass of Species i
EVINF	Vibrational Energy Based on Translational Temperature (Per Mass of Mixture)
F	Dummy Array of Derivatives for Integration Routine
FA	Constant, a, in Forward Chemical Rate Constant Expression
FB	Exponent, b, on Temperature Term for Forward Rate Constant
FC	Constant, c, in Exponential Term of Forward Rate Constant
GLVBK	Indicator Used to Set GVBRIK to Proper Value ($\bar{\epsilon}_v$, ϵ_{v_∞}, $\bar{\epsilon}_v$ or $\bar{G}_v$)
ICØUNT	Indicator for Identifying a Particular Integration Interval
IND	Indicator Used to Give Proper Matching Parameter
LIMX	Number of Points Defining Matching Parameter Distribution

FORTRAM SYMBOL	DEFINITION
LPRNT	Indicator Used to Give a Particular Input Data Printout
N3	Total Number of Species Excluding Inert Species
N4	Number of Electronic Species Considered
N5	Number of Vibrational Species Considered
NL	Number of Integrated Parameters
PBRH	Step-Size Control $(f \cdot h/y)$
PH	Stability Parameter $= -h\left(\frac{f_3 - f_2}{y_3 - y_2}\right)$
QTFI	Partition Function Based on Temperature Tf_i
QTVI	Partition Function Based on Temperature Tv_i
QTT	Partition Function Based on Translational Temperature
STEP	Integration Step Size
TABAP	Matching Parameter Array
TABX	X-coordinate of Matching Parameter
TABY	Y-coordinate of Matching Parameter
TAUADJ	Parameter Used to Adjust Vibrational Time Constant
TFI	Mean Temperature Used in Treanor's Analysis
UV	Indicator Used to Give Preferential or Nonpreferential Vibrational Relaxation Model
X	Streamline X-coordinate Measured in Arbitrary X-Y Cartesian Coordinate System
XMU	Catalytic Efficiencies for Chemical Species
XSTØP	Total Distance to be Integrated Along Streamtube
Y	Streamline Y-coordinate Measured in Arbitrary X-Y Cartesian Coordinate System
YY	Dummy array for storing Ordinates of Integrated Parameters

The computer program described in this report has been written to use only the cgs system of units. The equations for vibrational and electronic relaxation time constants, internal to the program, and the equations used for the input of chemical rate constants are only correct as written in the cgs system. To allow the program user to work with either the U.S. Customary System (U.S.) or the International System of Units (S.I.), a subroutine would have to be written to convert all input data ~~into cgs units~~. A related subroutine could be used to convert cgs output data into the desired system. The units previously listed would furnish the basis of these unit conversions.

Difficulty may be experienced in converting chemical rate constants, expressed as a function of temperature only, from Rankine to Kelvin. Assume that the rate constant is known in the proper form based on temperature in °R,

$$K = A T_R^{B} e^{-\frac{1000C}{T_R}}$$

To find the input data constants, a, b, and c, which will be used within the program with temperature in °K,

$$K = a T_K^{b} e^{-\frac{1000c}{T_K}}$$

it can be shown that

$$a = (1.8)^B A$$

$$b = B$$

$$c = C/1.8$$

A further correction to a is needed depending on the units used for species concentration.

SECTION I

INTRODUCTION

The objective of this study was to modify an existing one-dimensional reacting gas flow computer program, Reference 1, to include vibrational and electronic relaxation processes and chemical coupling. This older program had the capability of predicting test section conditions following the nonequilibrium expansion of air in the nozzle of an arc-heated experimental hypersonic facility. It could also be applied to the shock layer analysis of nonequilibrium flow over test models placed in such a nonequilibrium and nonuniform test section flow as well as full scale atmospheric entry flow fields. Nonequilibrium vibrational and electronic excitation can be expected to become more important as the enthalpy levels of test facilities are increased in an effort to more closely simulate the full scale atmospheric entry environment of current and future space vehicles. This consideration led to the requirement for an improved reacting gas program.

A review of the current state-of-the-art showed that the early work of Treanor and Marrone on a nonpreferential coupled vibration model, Reference 2, had been continued to develop a simple preferential model, Reference 3. In 1965 Treanor presented a sophisticated analysis, Reference 4, of preferential dissociation from excited vibrational levels which are not in a Boltzmann distribution. The model proposed in Reference 3 was adopted for this study since it was considered to be sufficiently accurate for engineering analysis, considering the many uncertainties in the basic data needed for these calculations, and was not much more difficult to program than the original nonpreferential model of Reference 2. No foreseeable difficulty was anticipated in extending the analysis to include electronic processes.

The basic design of the nonequilibrium program was to remain unchanged even though a completely new computer program was formulated and written. Subroutines would be added, where necessary, to cover the new logic required by the inclusion of finite vibrational and electronic relaxation processes. The basic reasons for writing a new program stem from the need to expand the chemical model to include more species and reactions and the need to include a greater number of integrated variables in the form of vibration and electronic parameters. Both effects resulted in changes to the size of storage arrays and the indexing system so extensively used throughout the program.

SECTION II

THEORETICAL FORMULATION

1. BASIC APPROACH

An effort was made in the new program to formulate the input of chemical species in a manner that will allow the chemical model to be easily altered or replaced. In this way, it will be possible to separately study various chemical models such as an air (oxygen-nitrogen) model, a hydrogen-oxygen model, a carbon-hydrogen-nitrogen-oxygen model, etc. It will also provide flexibility in performing future studies of the relative importance of various species and reactions included in the chemical model. At present, our primary interest lies in the air model which will be enlarged from its present state. Provision is made within the program to include up to fifty reactions and twenty species. The two new species which are added to the air chemistry model are O^- and O_2^-.

Along with the enlargement of the chemical model, it is also necessary to make provision within the program for finite changes in the vibrational energy of each diatomic species and changes in the electronic energy for all species, both monatomic and diatomic. This implies a step-wise integration of vibration and electronic energies similar to that currently being performed on the chemical species concentrations. The inclusion of these other energy modes in the formulation further complicates the flow equation which relates the changes in chemical composition, and now changes in vibrational and electronic energies, to the fluid properties through a differential expression for the local translational temperature, T_t . In the revised version of the program, vibrational and electronic energies are associated with their own individual temperatures, T_{v_i} , and T_{e_i} , respectively, which are different from the translational temperature. The relationships between these new temperatures and the translational temperature will become more apparent in a later development of the flow equation. The program is formulated in a very general way so that various assumptions can easily be made as to the vibrational and electronic state of the model.

Two forms of coupling vibrational relaxation to chemical relaxation were included in Treanor's model. One form pertains to the effect of vibration on dissociation; whereas the other pertains to the effect of dissociation on vibration. The first effect is introduced in the form of a coupling factor, V_{v_i} (one for each applicable diatomic species), which is used to modify the equilibrium value of the chemical reaction rate constant for those reactions in which chemical bonds are broken. From this standpoint, the coupling factor may be applied to either the forward or reverse reaction rate constant. Although the effect of electronic excitation on the chemistry processes is not as well understood, provision is also made in the program for including the effect of electronic relaxation on the chemical rate constants in the form of a similar coupling factor. At present, all of these electronic coupling factors will be set to unity, shunting out their effect, because of a present day lack of knowledge. However, it will be possible with this type of formulation to maintain complete generality within the program.

The second form of coupling employed by Treanor occurs through terms included in the vibrational rate expression for each diatomic species. These terms pertain to the vibrational energy lost, E_{v_i}, or gained, G_{v_i}, by the destruction or formation of a molecular species, respectively. Similar terms expressing the gain or loss of electronic energy from the formation and destruction of chemical species are included in the new formulation. The method of evaluating such terms for the electronic case is still quite questionable and it is necessary to again shunt all of these terms from the program until a better understanding of them has been obtained.

Another part of the program modification deals with the expressions for the individual species thermodynamic properties, enthalpy and specific heat. In the old version of the nonequilibrium chemistry program species thermodynamic properties were based on an equilibration of the vibrational and electronic temperatures to the local translational temperature. The new expressions are not as restrictive and contain provision for including individual species vibrational and electronic thermal effects. The new expressions are based on a rigid rotator cutoff harmonic oscillator model and it is presumed that there is no coupling between the various internal energy modes.

The final modification is the inclusion of Treanor's integration procedure as described in Reference 5. This procedure is designed to help overcome the difficulty associated with the numerical integration of a set of coupled differential equations with greatly differing time constants. In this type of problem, commonly referred to as the "stiff" equation problem, step size is determined by the fastest rate and the region of integration is set by the slowest rate. The term "stiff" refers to an extreme sensitivity of the rate of a parameter to small deviations of the integrated value from the true curve. Treanor's procedure is a modified version of the standard fourth-order Runge-Kutta integration technique which is specifically designed to minimize the "stiffness" effect and permit a larger integration step size. In regions of the integration process where "stiffness" is not a problem, Treanor's procedure becomes identical to the Runge-Kutta procedure. Thus, the new integration scheme is designed to furnish the same accuracy but at an improved program run time.

2. ONE-DIMENSIONAL NONEQUILIBRIUM FLOW ANALYSIS

This section presents the reformulation of the theory used in the nonequilibrium chemistry program to include finite vibrational and electronic relaxation processes and the coupling effects between these energy modes and the chemistry. We begin by presenting the three fluid conservation equations.

Conservation of Mass

$$\rho u A = M \tag{1}$$

Conservation of Momentum

$$\frac{dp}{ds} = -\rho u \frac{du}{ds} \tag{2}$$

Conservation of Energy

$$\frac{dh}{ds} + u\frac{du}{ds} = 0 \tag{3}$$

To these equations we add expressions relating to the thermodynamic state of the gas media in the form of the state equations and the definition for enthalpy of the gaseous media.

Equation of State

$$p = \rho R T_t \sum_{i=1}^{N_1} m_i \tag{4}$$

Definition of Enthalpy

$$h = \sum_{i=1}^{N_1} m_i w_i h_i(T_t, T_{v_i}, T_{e_i}) \tag{5}$$

These five equations are taken directly from Reference 1 with the exception of the modification to Equation (5) to include the separate effects of the vibration and electronic energy modes.

The expression for the chemical rate of change of a species mole/mass ratio with distance was basically defined in Reference 1 but due to the inclusion of vibrational and electronic modes of excitement it has been modified accordingly:

Chemical Rate Expression

$$\left(\frac{dm_i}{ds}\right)_{NET} = \frac{1}{\rho u} \sum_{k=1}^{N_2} (\beta_{k,i} - \alpha_{k,i}) \Big[Kf_k(T_t, T_{v_i}, T_{e_i}) \prod_{j=1}^{N_1} (\rho m_j)^{\alpha_{k,j}} - Kb_k(T_t, T_{v_i}, T_{e_i}) \prod_{j=1}^{N_1} (\rho m_j)^{\beta_{k,j}} \Big] \tag{6}$$

The coupling effects of the vibrational and electronic modes on the chemistry appear in the forward and backward chemical reaction rate constants, Kf_k and Kb_k. These coupling effects are introduced in the form of coupling factors V_{v_i} and V_{e_i} for the vibrational and electronic modes, respectively. The new rate constants are defined as follows:

$$Kf_k \equiv Kf_k(Tt, Tv_i, Te_i) = Kf_k(Tt) \cdot \prod_{i=1}^{N_1} Vv_i^{\, fv_{k,i}} \cdot \prod_{i=1}^{N_1} Ve_i^{\, fe_{k,i}} \tag{7a}$$

$$Kb_k \equiv Kb_k(Tt, Tv_i, Te_i) = Kb_k(Tt) \cdot \prod_{i=1}^{N_1} Vv_i^{\, bv_{k,i}} \cdot \prod_{i=1}^{N_1} Ve_i^{\, be_{k,i}} \tag{7b}$$

The second form of coupling discussed by Treanor in References 2 and 3 pertains to the chemical effect on vibrational energy rates due to the formation and destruction of species. The relationship for the vibrational energy rate, shown in Equation (8) below, is derived from an energy balance as described in Appendix I. For a given mass of gaseous mixture, there are three contributing factors to the rate of change of the vibrational energy state of the gas. One effect is due entirely to molecular excitement, no consideration being given to chemical reaction. The other two effects account for the gain and loss of vibrational energy due to the formation and destruction of chemical species, respectively. These three terms appear in the braced quantity in Equation (8) below. The remaining term in the equation pertaining to the net chemical change is derived from the fact that the energy rate given by Equation (8) is based on a mass of species "i" rather than a mass of mixture basis. It accounts for the fact that the mass of species "i" changes with distance along the streamtube, whereas the mass of mixture remains constant. The resultant vibrational energy change with streamtube distance is expressed by:

$$\frac{d\epsilon v_i}{ds} = -\frac{\sum_{k=1}^{N_2} Ev_i\left[\left(\frac{dm_i}{ds}\right)_{k_{FORM.}} - \left(\frac{dm_i}{ds}\right)_{k_{DEST}}\right]_{NET}}{w_i\, m_i^2} + \frac{1}{m_i w_i}\left\{\frac{1}{u}\left(\frac{Ev_{i_\infty} - Ev_i}{(\tau v_i)_m}\right) - \frac{\sum_{k=1}^{N_2} \bar{E}v_{k,i}\left(\frac{dm_i}{ds}\right)_{k_{DEST}}}{m_i} + \frac{\sum_{k=1}^{N_2} \bar{G}v_{k,i}\left(\frac{dm_i}{ds}\right)_{k_{FORM.}}}{m_i}\right\} \tag{8}$$

Since for any species a vibrational temperature is defined by the vibrational energy, the vibrational temperature derivative is computed and integrated. This avoids an iterative calculation of vibrational temperature from the vibrational energy. Thus,

$$\frac{dTv_i}{ds} = \left(\frac{dTv_i}{d\epsilon v_i}\right)\left(\frac{d\epsilon v_i}{ds}\right) \tag{8a}$$

where the first term on the right hand side is computed in closed form from Equation (29) below.

The terms $(dm_i/ds)_k$ for both species formation and destruction are positive quantities in Equation (8) and are defined as follows:

$$\left(\frac{dm_i}{ds}\right)_{k_{FORM.}} = \frac{1}{\rho u}\left[\beta_{k,i} Kf_k \prod_{j=1}^{N_1} (\rho m_j)^{\alpha_{k,j}} + \alpha_{k,j} Kb_k \prod_{j=1}^{N_1} (\rho m_j)^{\beta_{k,j}}\right] \quad (9)$$

$$\left(\frac{dm_i}{ds}\right)_{k_{DEST.}} = \frac{1}{\rho u}\left[\alpha_{k,i} Kf_k \prod_{j=1}^{N_1} (\rho m_j)^{\alpha_{k,j}} + \beta_{k,j} Kb_k \prod_{j=1}^{N_1} (\rho m_j)^{\beta_{k,j}}\right] \quad (10)$$

Combining Equations (9) and (10), as shown below, yields the net change in chemical species with streamtube distance which is identical with the expression in Equation (6).

$$\left(\frac{dm_i}{ds}\right)_{NET} = \sum_{k=1}^{N_2}\left[\left(\frac{dm_i}{ds}\right)_{k_{FORM.}} - \left(\frac{dm_i}{ds}\right)_{k_{DEST.}}\right] \quad (11)$$

The relationship shown below, and similar to that presented in Equation (8) for vibrational energy, expresses the rate of change of electronic energy with streamtube distance which is used in the computer program. The form of the term dependent on the electronic relaxation time constant, τe_i, is more fully discussed in Section II.6.

$$\frac{d\epsilon e_i}{ds} = \frac{\sum_{k=1}^{N_2} Ee_i\left[\left(\frac{dm_i}{ds}\right)_{k_{FORM.}} - \left(\frac{dm_i}{ds}\right)_{k_{DEST.}}\right]}{W_i\; m_i^2} + \frac{1}{m_i W_i}\left[\frac{1}{u}\sum_{j=1}^{N_1}\left(\frac{Ee_i(Tv_j) - Ee_i}{\tau e_{i,j}}\right)\right.$$

$$\left. - \frac{\sum_{k=1}^{N_2} Ee_{k,i}\left(\frac{dm_i}{ds}\right)_{k_{DEST.}}}{m_i} + \frac{\sum_{k=1}^{N_2} \bar{G}e_{k,i}\left(\frac{dm_i}{ds}\right)_{k_{FORM.}}}{m_i}\right] \quad (12)$$

Since for any species an electronic temperature is defined by the electronic energy the electronic temperature derivative is computed and integrated to avoid the iterative calculation of temperature from a known energy. Thus,

$$\frac{dTe_i}{ds} = \left(\frac{dTe_i}{d\epsilon e_i}\right)\left(\frac{d\epsilon e_i}{ds}\right) \tag{12a}$$

where the first derivative in the right hand side is computed in closed form from Equation (14), below. Because of the lack of knowledge of Te_i for other than the pure species N_2, the computer program integrates the electronic temperature of N_2 and equates all other species electronic temperatures to this value. As stated earlier, it is also presently beyond the state-of-the-art to evaluate the terms $\bar{E}e_{k,i}$ and $Ge_{k,i}$. Therefore, they will be set equal to Ee_i in Equation (12), shunting out their effect and leaving for the species N_2,

$$\frac{d\epsilon e_i}{ds} = \frac{1}{m_i w_i}\left[\frac{1}{u}\left(\frac{Ee_i(Tv_i) - Ee_i}{\tau e_i}\right)\right] \tag{13}$$

The energy terms $Ee_i(Tv_i)$ and Ee_i are obtained from the following expression which is based on the electronic partition function evaluated at the different energy levels for $T = Tv_i$ and $T = Te_i$, respectively:

$$Ee_i(T) = \epsilon e_i m_i w_i = R m_i \frac{\sum_{l=1}^{L} EL_{i,l}\, g_{i,l} \exp\left(\frac{-EL_{i,l}}{T}\right)}{\sum_{l=1}^{L} g_{i,l} \exp\left(\frac{-EL_{i,l}}{T}\right)} \tag{14}$$

To obtain the flow equation, which relates the various finitely changing energy modes to the flow properties through the energy conservation equation, one begins by differentiating the enthalpy expression presented in Equation (5). This yields

$$\frac{dh}{ds} = \sum_{i=1}^{N_1} m_i w_i \frac{dh_i(Tt, Tv_i, Te_i)}{ds} + \sum_{i=1}^{N_1} w_i h_i(Tt, Tv_i, Te_i)\frac{dm_i}{ds} \tag{15}$$

Looking for the moment at $\frac{dh_i}{ds}(Tt, Tv_i, Te_i)$, we find

$$\frac{dh_i(T_t, T_{v_i}, T_{e_i})}{ds} = cp_i(T_t)\frac{dT_t}{ds} + \frac{dh_{v_i}}{ds} + \frac{dh_{e_i}}{ds} \tag{16}$$

which, when substituted into Equation (15), results in the following expression:

$$\frac{dh}{ds} = \sum_{i=1}^{N_1} m_i w_i \, cp_i(T_t)\frac{dT_t}{ds} + \sum_{i=1}^{N_1} m_i w_i \frac{dh_{v_i}}{ds} + \sum_{i=1}^{N_1} m_i w_i \frac{dh_{e_i}}{ds} + \sum_{i=1}^{N_1} w_i h_i(T_t, T_{v_i}, T_{e_i})\frac{dm_i}{ds} \tag{17}$$

The terms dh_{v_i}/ds and dh_{e_i}/ds are identically equal to $d\epsilon_{v_i}/ds$ and $d\epsilon_{e_i}/ds$ in Equations (8) and (12), respectively.

The final step in the process of determining the flow equation is to relate dh/ds in Equation (17) to the proper "matching parameter" obtained from an equilibrium solution of the same flow field. This matching parameter may be streamtube area, streamtube pressure, or streamtube velocity. The velocity matching relationship is the easiest to obtain since it simply involves equating Equation (3) to Equation (17) and solving for dT_t/ds as shown below:

Flow Equation - (Velocity Match)

$$\frac{dT_t}{ds} = -\left[\sum_{i=1}^{N_1} m_i w_i \, cp_i(T_t)\right]^{-1} \cdot \left[u\frac{du}{ds} + \sum_{i=1}^{N_1} m_i w_i \frac{dh_{v_i}}{ds} + \sum_{i=1}^{N_1} m_i w_i \frac{dh_{e_i}}{ds} + \sum_{i=1}^{N_1} w_i h_i(T_t, T_{v_i}, T_{e_i})\frac{dm_i}{ds}\right] \tag{18a}$$

The flow equation for pressure match is easily obtained from Equation (18a) through the use of the momentum relationship given in Equation (2). The resulting expression is

Flow Equation - (Pressure Match)

$$\frac{dT_t}{ds} = \left[\sum_{i=1}^{N_1} m_i w_i \, cp_i(T_t)\right]^{-1} \cdot \left[\frac{1}{\rho}\frac{dp}{ds} - \sum_{i=1}^{N_1} m_i w_i \frac{dh_{v_i}}{ds} - \sum_{i=1}^{N_1} w_i h_i(T_t, T_{v_i}, T_{e_i})\frac{dm_i}{ds} - \sum_{i=1}^{N_1} m_i w_i \frac{dh_{e_i}}{ds}\right] \tag{18b}$$

The derivation of the expression for area match is more involved and requires combining differential forms of the state equation, continuity relationship, and momentum relationship to arrive at an expression for du/ds in terms of dA/ds. This expression is then substituted in Equation (18a) to produce

Flow Equation - (Area Match)

$$\frac{dT_t}{ds} = -\left[\sum_{i=1}^{N_1} m_i w_i \, cp_i(T_t) + \frac{\rho R \sum_{i=1}^{N_1} m_i}{(p/u^2 - \rho)}\right]^{-1} \cdot \left[\sum_{i=1}^{N_1} m_i w_i \frac{dh_{v_i}}{ds} + \sum_{i=1}^{N_1} m_i w_i \frac{dh_{e_i}}{ds} + \sum_{i=1}^{N_1} w_i h_i(T_t, T_{v_i}, T_{e_i})\frac{dm_i}{ds} + \frac{\rho R T_t \sum_{i=1}^{N_1} \frac{dm_i}{ds} - \frac{p}{A}\frac{dA}{ds}}{(p/u^2 - \rho)}\right] \tag{18c}$$

One more differential equation relating a flow property to the appropriate matching parameter is required in the solution of the one-dimensional reacting gas problem. For the cases of velocity and pressure matching, one can use the momentum equation and integrate pressure or velocity, respectively, as shown below.

Velocity Match ($\frac{du}{ds}$ is known)

$$\frac{dp}{ds} = -\rho u \frac{du}{ds} \tag{19}$$

Pressure Match ($\frac{dp}{ds}$ is known)

$$\frac{du}{ds} = -\frac{1}{\rho u}\frac{dp}{ds} \tag{20}$$

In the area match case, velocity will be the second integrated flow parameter as given below:

Area Match ($\frac{dA}{ds}$ is known)

$$\frac{du}{ds} = \frac{\rho R T_t \sum_{i=1}^{N_r} \frac{dn_i}{ds} + \rho R \sum_{i=1}^{N_i} n_i \frac{dT_t}{ds} - \frac{p}{A}\frac{dA}{ds}}{u\left(p/u^2 - \rho \right)} \qquad (21)$$

This section deals with the application of this modified theoretical development to the nonequilibrium problem. The first task is to define a set of starting conditions. In the case of external flow the starting point is generally assumed to lie immediately downstream of the shock front and the pressure-match relationship for dT_t/ds (Equation (18b)) is used. For nozzle flow where the area-match relationship for dT_t/ds (Equation (18c) is used, one finds that a removable singularity exists at a point in the flow where the first bracketed quantity in Equation (18c) goes to zero. It can be shown that this bracketed quantity is equal to the difference between the frozen Mach number squared and unity. Furthermore, this point occurs downstream of the throat and it is necessary to start the nozzle case downstream of this singularity. Figures 1 and 2 can be used to determine the approximate location of the singular point in the nozzle from known equilibrium conditions. There is no such singularity in the pressure-match relationship. In the external flow problem, translational temperature, T_t , is based on immediate equilibration of the translational and rotational modes of excitement behind the shock. The vibrational temperatures, T_{v_i} , for all diatomic species and the electronic temperatures, T_{e_i} , for all applicable species will be set equal to the free stream temperature. In passing through the shock front the chemistry is assumed frozen and equal to the free stream composition. In the nozzle case the composition and all temperatures will be set equal to equilibrium values for tunnel test conditions.

Having described the starting point conditions, we proceed with a description of the procedure for advancing downstream. This procedure is described below:

<u>Step 1</u> - Knowing the initial values of T_t and T_{v_i} , compute the vibration-dissociation coupling factors, V_{v_i} , for each diatomic species from Equations (25), (26), and (27). The terms V_{e_i} will be temporarily set equal to unity.

<u>Step 2</u> - The forward and backward chemical reaction rates based on translational temperature will be evaluated for each reaction and entered into Equations (7a and 7b) along with the terms computed in Step 1 above. The modified rate constants, as functions of the three temperatures, T_t , T_{v_i} , and T_{e_i} , will then be determined.

<u>Step 3</u> - Once the chemical rate constants are available, one can proceed with the evaluation of the net chemical rates for each species, $(dn_i/ds)_{NET}$, from Equation (6) and the species formation and destruction terms $(dn_i/ds)_{k_{FORM}}$ and $(dn_i/ds)_{k_{DEST}}$.

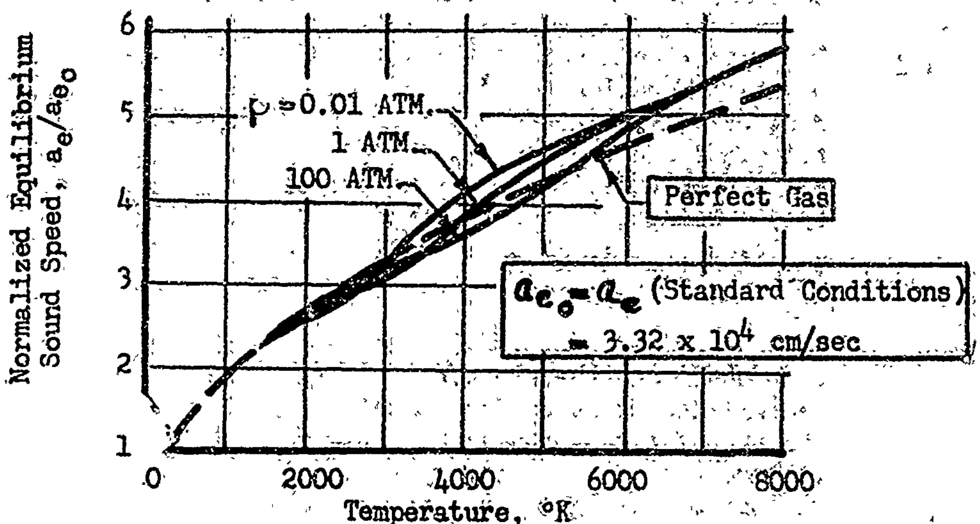


Figure 1. Equilibrium Sound Speed for Mixture of Reacting O_2 and O and Inert N_2 (Reference J. Der, NASA TR R-164)

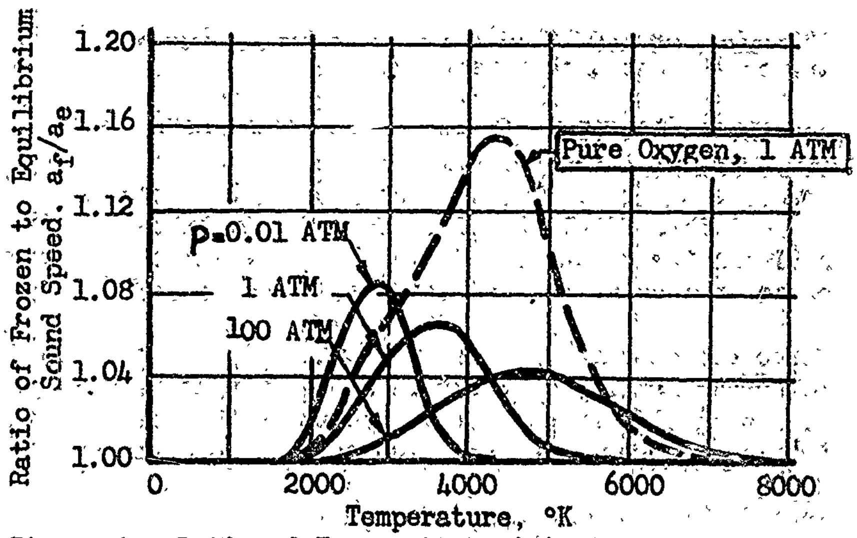


Figure 2. Ratio of Frozen to Equilibrium Sound Speeds For Mixture of Reacting O_2 and O and Inert N_2 (Reference J. Der, NASA TR R-164)

Step 3 - (continued)

from Equations (9) and (10) which are used in Equations (8) and (12) for the vibrational and electronic rates, respectively.

Step 4 - The vibrational energy terms $E_{v_{i,\infty}}$ and E_{v_i} are evaluated by means of Equation (29) using the temperatures T_t and T_{v_i}, respectively. The energy terms $\bar{E}_{v_{k,i}}$ and $\tilde{G}_{v_{k,i}}$, are evaluated from Equation (29) and Tables VI and VII. The vibrational relaxation time, $(\tau_{v_i})_m$, is determined from Equations (30) and (31). Using this and information from Step 3 above, one can evaluate the vibrational energy rates from Equation (8) for each diatomic specie.

Step 5 - For the present, E_{e_i}, $\bar{E}_{e_{k,i}}$, and $\tilde{G}_{e_{k,i}}$, will all be set equal to each other and the electronic energy rate for molecular nitrogen will be computed from Equation (13). The electronic temperature of nitrogen will be integrated and the electronic temperature of all other species will be assumed to be equal to that of nitrogen. The terms $E_{e_i}(T_{v_i})$ and E_{e_i} will be evaluated from Equation (14) for $T_{v_{N_2}}$ and $T_{e_{N_2}}$, respectively.

Step 6 - The final step prior to evaluating the appropriate flow equation is to evaluate $c_{p_i}(T_t)$ and $h_i(T_t, T_{v_i}, T_{e_i})$ for each species from Equations (22) and (23).

Step 7 - Evaluate the appropriate flow equation, Equation (18), depending on the matching parameter used.

Step 8 - Equations (6), (8a), (12a), (18) and one of the Equations (19 - 21) will be forwardly integrated to the next downstream point in the streamtube. A new chemical composition, a new set of vibrational and electronic temperatures, a new translational temperature, and finally a new value of u or p will be determined at the new station.

Step 9 - Since the matching parameter is input to the program, its new value can readily be computed at the new downstream point. The remaining flow properties at the new point are obtained from the mass conservation equation and the equation of state.

Having performed these nine steps, one completely defines all of the required parameters at the new station and needs only to repeat the procedure to traverse the remainder of the streamtube.

3. THERMODYNAMIC MODEL

The expressions for the thermodynamic properties $h_i(T_t, T_{v_i}, T_{e_i})$ and $c_{p_i}(T_t)$ for the uncoupled, cutoff harmonic oscillator model are shown below:

$$h_i(T_t, T_{r_i}, T_{e_i}) = \frac{R}{w_i}\left\{\frac{5}{2}T_t + T_t + \left[\frac{\theta_i}{\exp\left(\frac{\theta_i}{T_{v_i}}\right)-1} - \frac{N_i\theta_i}{\exp\left(\frac{N_i\theta_i}{T_{v_i}}\right)-1}\right] + \frac{\sum_{l=1} EL_{i,l}\, g_{i,l} \exp\left(\frac{-EL_{i,l}}{T_{e_i}}\right)}{\sum_{l=1} g_{i,l} \exp\left(\frac{-EL_{i,l}}{T_{e_i}}\right)}\right\} + h_{0_i} \tag{22}$$

$$cp_i(T_t) = \frac{R}{w_i}\left[\frac{5}{2} + 1\right] \tag{23}$$

In the expression for species enthalpy the four terms within the braces are translational energy, rotational energy, vibrational energy, and electronic energy. The term h_{0_i} represents the reference or heat of formation energy for the particular species. The vibrational energy is based on a cut-off simple harmonic oscillator for diatomic species to ensure consistency with the vibrational coupling analysis. It is also necessary, since nonequilibrium vibrational and electronic energies are being considered, to separate the vibrational and electronic energy modes from the translational and rotational energy modes. The above model accomplishes this separation. It assumes a rigid rotator with rotational temperature equal to the translational temperature. Diatomic species have a fixed number of equally spaced vibrational levels, shown in Table I independent of either translational or electronic temperature. These data were obtained from Reference 6 .

Table I. Vibrational Energy Constants

Specie	θ_i (°K)	N
N_2	3374	33
O_2	2256	26
NO	2719	27
NO^+	3397	36
N_2^+	3129	32
O_2^+	2652	28
O_2^-	1830	29

The electronic energy levels are assumed as constants, and are listed in Table II. These are based on data presented in References 7 and 8 . Energies have been included that correspond to one electron excited to the $n = 5$ shell.

Table II. Electronic Energy Levels and Degeneracies

Species	l = 0		l = 1		l = 2		l = 3		l = 4		l = 5		l = 6		l = 7	
	g	EL	g	EL	g	EL	g	EL	g	EL	g	EL	g	EL	g	EL
N_2	1	0	3	71700	6	85500	2	99400	6	126000	1	137000	—	—	—	—
O_2	3	0	2	11350	1	18900	3	51500	1	52100	3	71000	—	—	—	—
NO	2	0	2	174	2	63600	4	65400	4	75300	2	76800	2	87600	—	—
NO^+	1	0	6	58000	3	85100	6	105000	2	105800	—	—	—	—	—	—
N_2^+	2	0	4	13200	2	36800	2	93000	—	—	—	—	—	—	—	—
O_2^+	4	0	8	46000	4	55000	4	70000	—	—	—	—	—	—	—	—
O_2^-	4	0	4	19300	4	34800	—	—	—	—	—	—	—	—	—	—
N	4	0	10	27700	6	41500	30	123400	64	139000	378	156000	—	—	—	—
O	5	0	4	253	5	22850	1	48500	8	107800	24	126000	53	140000	149	148000
N^+	1	0	8	145	5	22100	1	50200	5	72200	24	142200	131	171025	340	216185
O^+	3	0	10	38600	6	58100	12	172800	10	239000	18	268000	72	301000	840	364000
O^-	1	0	NOT KNOWN													
e^-	2	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
A	1	0	12	136000	36	153000	108	165000	348	174800	—	—	—	—	—	—

The higher energy levels have been summed into groups using energies weighted by their degeneracies. This approach follows the suggestion of Gilmore who pointed out that no problems with series convergence will be encountered using this approach while good accuracy is maintained since the chemistry limits the number of molecules in the extreme upper levels. A comparison with accepted values showed a high accuracy of species enthalpy computed with this model at 5500°K. Subsequent comparisons have been made for an air mixture up to 16,000°K. An examination of the equilibrium air compositions presented in Reference 9 indicates that the highest concentrations of molecular species at high temperatures occur at the highest density ratio shown. Thus, an evaluation of the accuracy of computing thermodynamic properties was made for $\rho/\rho_o = 1$, where ρ_o is air density at 1 atmosphere of pressure at 0°C. The percentage error in species enthalpy computed with the above model was found by comparing to corresponding data in Reference 7. Mole fractions at equilibrium for the species N_2, O_2, and NO were obtained from Reference 9. The error in evaluating the enthalpy of an air mixture, which is proportional to the product of the species mole fraction and the error in species enthalpy, was computed for these three molecular species. The results, given in Table III, show an error of less than one percent which decreases with increasing temperature.

Table III. Evaluation of SD Thermodynamic Data

$\rho/\rho_o = 1.0$

Temperature, °K	$\Delta h_{error}/h_{mixture}$		
	N_2	NO	O_2
6,000	.0068	.0004	.0004
8,000	.0048	.0002	———
10,000	.0027	.0001	———
12,000	.0008	———	———
14,000	.0003	———	———
16,000	.0001	———	———

4. CHEMICAL MODEL FOR AIR

The recent publication of a consensus opinion on a standard chemical kinetics model for flow field analysis, Reference 10, has simplified the problem of selecting a set of air reactions and the best available rate data. It has been decided to use the Bortner model for air as presented in Tables IV and V. The computer program will accept up to 20 species and 50 reactions. The sample cases have been run with a reduced number of species and reactions, however all data for the full air model are given in these tables. Bortner presents two sets of rate data. The 'high temperature' data, Table IV, are applicable when the reaction is predominantly endothermic, while the 'low temperature' data, Table V, are applicable when the reaction is exothermic. The program will accept either set of data, as well as any other set if expressed in the same form. To avoid discontinuities in the data and possible difficulties in the integration procedure, no provision is made to automatically switch from one set to another during a run. Thus, for a nozzle

Table IV Bortner's Chemical Model, High Temperature Data

	Reaction	Forward			Reverse		
		a^* $\left(\frac{cm^3}{g\text{-mole}}\right)^{\alpha}\left(\frac{1}{sec}\right)$	b —	c $(°K)$	a^* $\left(\frac{cm^3}{g\text{-mole}}\right)^{\beta}\left(\frac{1}{sec}\right)$	b —	c $(°K)$
1.	$O_2 + M \rightleftharpoons O + O + M$ $M = O_2$ O N_2 N, NO, AR	3.25×10^{13} 9.04×10^{13} 0.723×10^{13} 0.364×10^{13}	-1 -1 -1 -1	59.4 59.4 59.4 59.4	2.72×10^{10} 7.61×10^{10} 0.616×10^{10} 0.301×10^{10}	-0.5 -0.5 -0.5 -0.5	0 0 0 0
2.	$N_2 + X \rightleftharpoons N + N + X$ $X = N_2$ O_2, O, NO, AR	4.76×10^{11} 1.929×10^{11}	-0.5 -0.5	113.1 113.1	2.64×10^{10} 1.038×10^{10}	-0.5 -0.5	0 0
3.	$N_2 + N \rightleftharpoons N + N + N$	4.16×10^{14}	-1.5	113.1	2.32×10^{15}	-1.5	0
4.	$NO + M \rightleftharpoons N + O + M$ $M = NO, O, N$ O_2, N_2, AR	7.83×10^{15} 0.398×10^{15}	-1.5 -1.5	75.6 75.6	1.958×10^{15} 0.1015×10^{15}	-1.5 -1.5	0 0
5.	$O + NO \rightleftharpoons N + O_2$	3.19×10^{3}	1	19.7	9.64×10^{5}	0.5	3.6
6.	$O + N_2 \rightleftharpoons N + NO$	6.75×10^{7}	0	37.5	1.503×10^{8}	0	0
7.	$N_2 + O_2 \rightleftharpoons NO + NO$	8.44×10^{7}	-0.5	61.6	6.02×10^{4}	0	40.0
8.	$N_2 + Z \rightleftharpoons N_2^+ + e + Z$ $Z = N_2$ O_2 NO	150.7 60.2 60.2	0.5 0.5 0.5	181 181 181	9.43×10^{9} 3.62×10^{9} 3.62×10^{9}	-1 -1 -1	0 0 0
9.	$N_2 + W \rightleftharpoons N_2^+ + e + W$ $W = N, O, AR$	9.65×10^{10}	-1	181	6.16×10^{18}	-2.5	0
10.	$N_2 + e \rightleftharpoons N_2^+ + e + e$	1.327×10^{26}	-3	181	83.5×10^{32}	-4.5	0
11.	$O_2 + Z \rightleftharpoons O_2^+ + e + Z$ $Z = N_2$ O_2 NO	54.2 78.4 60.2	0.5 0.5 0.5	140 140 140	5.08×10^{9} 7.25×10^{9} 5.80×10^{9}	-1 -1 -1	0 0 0
12.	$O_2 + W \rightleftharpoons O_2^+ + e + W$ $W = N, O, AR$	6.62×10^{10}	-1	140	6.16×10^{18}	-2.5	0
13.	$O_2 + e \rightleftharpoons O_2^+ + e + e$	9.04×10^{9}	-3	140	83.5×10^{32}	-4.5	0
14.	$NO + M \rightleftharpoons NO^+ + e + M$ $M = N_2$ O_2 NO	4.40×10^{11} 17.47×10^{11} 0.0204×10^{11}	-1 -1 -1	107.9 107.9 107.9	22.1×10^{19} 87.0×10^{19} 0.1017×10^{19}	-2.5 -2.5 -2.5	0 0 0

14.	O_2	17.47×10^{11}	-1	107.9	87.0×10^{19}	-2.5	0
	NO	0.0204×10^{11}	-1	107.9	0.1017×10^{19}	-2.5	0
	N, O, AR	0.1204×10^{11}	-1	107.9	0.616×10^{19}	-2.5	0
15.	$NO + e \rightleftharpoons NO^+ + e + e$	1.688×10^{25}	-3	107.9	83.5×10^{32}	-4.5	0
16.	$N + M \rightleftharpoons N^+ + e + M$						
	$M = N_2$	3.98×10^{12}	-1	169	22.1×10^{19}	-2.5	0
	O_2	15.67×10^{12}	-1	169	87.0×10^{19}	-2.5	0
	NO	235×10^{12}	-1	169	0.1017×10^{19}	-2.5	0
	N, O, AR	0.1085×10^{12}	-1	169	0.616×10^{19}	-2.5	0
17.	$N + e \rightleftharpoons N^+ + e + e$	15.06×10^{25}	-3	169	83.5×10^{32}	-4.5	0
18.	$O + M \rightleftharpoons O^+ + e + M$						
	$M = N_2$	7.83×10^{11}	-1	158	22.1×10^{19}	-2.5	0
	O_2	30.7×10^{11}	-1	158	87.0×10^{19}	-2.5	0
	NO	464×10^{11}	-1	158	1304×10^{19}	-2.5	0
	N, O, AR	0.217×10^{11}	-1	158	0.616×10^{19}	-2.5	0
19.	$O + e \rightleftharpoons O^+ + e + e$	2.95×10^{11}	-3	158	83.5×10^{32}	-4.5	0
20.	$N + O \rightleftharpoons NO^+ + e$	9.04×10^{3}	0.5	32.4	18.08×10^{12}	-1	0
21.	$O + O \rightleftharpoons O_2^+ + e$	319.0	1	80.7	36.15×10^{12}	-1	0
22.	$N + N \rightleftharpoons N_2^+ + e$	48.2×10^{3}	0.5	67.8	54.2×10^{12}	-1	0
23.	$N_2^+ + O \rightleftharpoons N_2 + O^+$	6.02×10^{6}	0	0	27.1×10^{6}	0	23.0
24.	$N_2^+ + O \rightleftharpoons NO^+ + N$	6.02×10^{6}	[illegible]	0	10.84×10^{6}	0	35.4
25.	$N_2^+ + O_2 \rightleftharpoons N_2 + O_2^+$	6.02×10^{5}	0	0	9.04×10^{5}	0	40.9
26.	$N_2^+ + NO \rightleftharpoons N_2 + NO^+$	6.02×10^{6}	0	0	48.2×10^{6}	0	75.1
27.	$N^+ + O_2 \rightleftharpoons NO^+ + O$	6.02×10^{7}	0	0	18.07×10^{5}	0.5	87.2
28.	$O^+ + O_2 \rightleftharpoons O + O_2^+$	12.04×10^{6}	0	0	40.3×10^{5}	0	17.9
29.	$O^+ + NO \rightleftharpoons O + NO^+$	30.1×10^{5}	0	0	53.6×10^{5}	0	50.1
30.	$O^+ + N_2 \rightleftharpoons NO^+ + N$	18.07×10^{5}	0	0	7.23×10^{5}	0	12.4
31.	$O_2^+ + NO \rightleftharpoons O_2 + NO^+$	6.02×10^{6}	0	0	31.9×10^{6}	0	32.2
32.	$O_2^+ + N_2 \rightleftharpoons NO^+ + NO$	6.02×10^{6}	0	3	21.7×10^{3}	0.5	14.1
33.	$O_2^+ + N \rightleftharpoons NO^+ + O$	12.05×10^{7}	0	0	21.7×10^{5}	0.5	58.3
34.	$O_2 + e + Y \rightleftharpoons O_2^- + Y$						
	$Y = O_2$	90.6×10^{10}	0.5	0	241	2	5.1
	N_2	3.62×10^{10}	0.5	0	10.23	2	5.1
	O	1.088×10^{10}	0.5	0	3.37	2	5.1
35.	$O + e + Y \rightleftharpoons O^- + Y$ $Y = O_2, N_2, O$	36.25×10^{9}	0	0	421	1.5	17.0
36.	$O_2 + e \rightleftharpoons O^- + O$	6.02×10^{15}	-2	42.4	6.02×10^{4}	0	0
37.	$O_2^- + O \rightleftharpoons O_2 + O^-$	6.02×10^{6}	0	0	12.04×10^{6}	0	11.9

* Constants "a" must be multiplied by 10^6 prior to using them in Forward and Backward rate constant expressions.

2

Table V Bortner's Chemical Model, Low Temperature Data

	Reaction	Forward			Reverse		
		$\left(\frac{cm^3}{g\text{-mole}}\right)^{a^*\alpha}\left(\frac{1}{sec}\right)$	b	c ($^\circ K$)	$\left(\frac{cm^3}{g\text{-mole}}\right)^{a^*\beta}\left(\frac{1}{sec}\right)$	b	c ($^\circ K$)
1.	$O_2 + M \rightleftharpoons O + O + M$ $M = O_2$ O N_2 N, NO, AR	2.17×10^{13}	-1	59.4	1.813×10^{10}	-0.5	0
2.	$N_2 + X \rightleftharpoons N + N + X$ $X = N_2$ O_2, O, NO, AR	3.92×10^{13}	-1	113.1	2.18×10^{12}	-1	0
3.	$N_2 + N \rightleftharpoons N + N + N$	3.92×10^{13}	-1	113.1	2.18×10^{12}	-1	0
4.	$NO + M \rightleftharpoons N + O + M$ $M = NO$, O, N O_2, N_2, AR	1.325×10^{13}	-1	75.6	3.26×10^{12}	-1	0
5.	$O + NO \rightleftharpoons N + O_2$	6.02×10^{-1}	2	19.4	1.807×10^{2}	1.5	3.3
6.	$O + N_2 \rightleftharpoons N + NO$	6.75×10^{7}	0	37.5	1.503×10^{8}	0	0
7.	$N_2 + O_2 \rightleftharpoons NO + NO$	8.44×10^{7}	-0.5	61.6	6.02×10^{4}	0	40.0
8.	$N_2 + Z \rightleftharpoons N_2^+ + e + Z$ $Z = N_2$ O_2 NO	0.350×10^{13} 1.387×10^{13} 21.1×10^{13}	-1 -1 -1	181 181 181	2.18×10^{20} 8.70×10^{20} 130.4×10^{20}	-2.5 -2.5 -2.5	0 0 0
9.	$N_2 + W \rightleftharpoons N_2^+ + e + W$ $W = N$, O, AR	9.65×10^{10}	-1	181	6.16×10^{18}	-2.5	0
10.	$N_2 + e \rightleftharpoons N_2^+ + e + e$	1.327×10^{10}	-3	181	83.5×10^{32}	-4.5	0
11.	$O_2 + Z \rightleftharpoons O_2^+ + e + e$ $Z = N_2$ O_2 NO	2.35×10^{12} 9.04×10^{12} 136.5×10^{12}	-1 -1 -1	140 140 140	2.21×10^{20} 8.75×10^{20} 130.5×10^{20}	-2.5 -2.5 -2.5	0 0 0
12.	$O_2 + W \rightleftharpoons O_2^+ + e + W$ $W = N$, O, AR	6.62×10^{10}	-1	140	6.16×10^{18}	-2.5	0
13.	$O_2 + e \rightleftharpoons O_2^+ + e + e$	9.04×10^{9}	-3	140	83.5×10^{38}	-4.5	0
14.	$NO + M \rightleftharpoons NO^+ + e + M$ $M = N_2$ O_2 NO	4.40×10^{11} 17.47×10^{11} 0.0204×10^{11}	-1 -1 -1	107.9 107.9 107.9	22.1×10^{19} 87.0×10^{19} 0.1017×10^{19}	-2.5 -2.5 -2.5	0 0 0

	N, O, AR	0.1204×10^{11}	-1	107.	0.616×10^{19}	-2.5	0
15.	$NO + e \rightleftharpoons NO^+ + e + e$	1.688×10^{25}	-3	107.9	83.5×10^{32}	-4.5	0
16.	$N + M \rightleftharpoons N^+ + e + M$ $M = N_2$ O_2 NO N, O, AR	 3.98×10^{12} 15.67×10^{12} 235×10^{12} 0.1085×10^{12}	 -1 -1 -1 -1	 169 169 169 169	 22.1×10^{19} 87.0×10^{19} 0.1017×10^{19} 0.616×10^{19}	 -2.5 -2.5 -2.5 -2.5	 0 0 0 0
17.	$N + e \rightleftharpoons N^+ + e + e$	15.06×10^{9}	-3	169	83.5×10^{32}	-4.5	0
18.	$O + M \rightleftharpoons O^+ + e + M$ $M = N_2$ O_2 NO N, O, AR	 7.83×10^{11} 30.7×10^{11} 464×10^{11} 0.217×10^{11}	 -1 -1 -1 -1	 158 158 158 158	 22.1×10^{19} 87.0×10^{19} 1304×10^{19} 0.616×10^{19}	 -2.5 -2.5 -2.5 -2.5	 0 0 0 0
19.	$O + e \rightleftharpoons O^+ + e + e$	2.95×10^{11}	-3	158	83.5×10^{32}	-4.5	0
20.	$N + O \rightleftharpoons NO^+ + e$	45.1×10^{3}	0.5	32.4	9.04×10^{13}	-1	0
21.	$O + O \rightleftharpoons O_2^+ + e$	319	1	80.7	36.15×10^{12}	-1	0
22.	$N + N \rightleftharpoons N_2^+ + e$	48.2×10^{3}	0.5	67.8	54.2×10^{12}	-1	0
23.	$N_2^+ + O \rightleftharpoons N_2 + O^+$	6.02×10^{6}	0	0	27.1×10^{6}	0	23.0
24.	$N_2^+ + O \rightleftharpoons NO^+ + N$	6.02×10^{6}	0	0	10.84×10^{6}	0	35.4
25.	$N_2^+ + O_2 \rightleftharpoons N_2 + O_2^+$	6.02×10^{5}	0	0	9.04×10^{5}	0	40.9
26.	$N_2^+ + NO \rightleftharpoons N_2 + NO^+$	6.02×10^{6}	0	0	48.2×10^{6}	0	73.1
27.	$N^+ + O_2 \rightleftharpoons NO^+ + O$	6.02×10^{7}	0	0	18.07×10^{5}	0.5	87.2
28.	$O^+ + O_2 \rightleftharpoons O + O_2^+$	12.04×10^{6}	0	0	40.3×10^{5}	0	17.9
29.	$O^+ + NO \rightleftharpoons O + NO^+$	30.1×10^{5}	0	0	53.6×10^{5}	0	50.1
30.	$O^+ + N_2 \rightleftharpoons NO^+ + N$	18.07×10^{5}	0	0	7.23×10^{5}	0	12.4
31.	$O_2^+ + NO \rightleftharpoons O_2 + NO^+$	6.02×10^{6}	0	0	31.9×10^{6}	0	32.2
32.	$O_2^+ + N_2 \rightleftharpoons NO^+ + NO$	6.02×10^{6}	0	3	21.7×10^{3}	0.5	14.1
33.	$O_2^+ + N \rightleftharpoons NO^+ + O$	12.05×10^{7}	0	0	21.7×10^{5}	0.5	58.3
34.	$O_2 + e + Y \rightleftharpoons O_2^- + Y$ $Y = O_2$ N_2 O	 90.6×10^{10} 3.62×10^{10} 1.088×10^{10}	 0.5 0.5 0.5	 0 0 0	 241 10.23 3.37	 2 2 2	 5.1 5.1 5.1
35.	$O + e + Y \rightleftharpoons O^- + Y$ $Y = O_2, N_2, O$	36.25×10^{9}	0	0	421	1.5	17.0
36.	$O_2 + e \rightleftharpoons O^- + O$	6.02×10^{15}	-2	42.4	6.02×10^{4}	0	0
37.	$O_2^- + O \rightleftharpoons O_2 + O^-$	6.02×10^{6}	0	0	12.04×10^{6}	0	11.9

* Constants "a" must be multiplied by 10^{6} prior to using them in Forward and Backward rate constant expressions.

expansion flow problem where, for example, recombination reactions become predominant over dissociation reactions, the best choice is the low temperature set of data. For an external flow field streamline which starts at a shock wave the best data is the high temperature set, since endothermic reactions dominate most of the flow field and both sets are equally accurate near equilibrium. Both sets of data are consistent with the same equilibrium constants so that identical equilibrium composition will result from use of either set. The data in Reference 10 have been converted into values which are consistent with concentrations expressed in g-moles/g_m. The rate constants are given by the form

$$K = aT^{b} e^{-\frac{1000c}{T}} \tag{24}$$

and the tables list values for a, b, and c. Due to the fact that some values of the constant a are exceedingly large and may present machine computational difficulties in the evaluation of the chemical rate constants, all values of "a" shown in the table have been reduced by a factor of 10^6. In the program the rates are computed using the exact data furnished in the table and then multiplied by 10^6 to obtain the correct rate constants.

5. VIBRATIONAL RELAXATION EVALUATION

In this subsection the form of the expressions for the coupling factor and the energy terms will be presented and the evaluation of the expressions will be discussed with emphasis on the Bortner chemical model for air. The vibrational coupling factors, V_{v_i}, have been thoroughly defined by Treanor for the cut-off harmonic oscillator model in terms of the vibrational partition function evaluated at three temperatures, T_t, T_{v_i}, and an effective temperature, T_{f_i}, given by the relationship

$$\frac{1}{T_{f_i}} = \frac{1}{T_{v_i}} - \frac{1}{T_t} - \frac{1}{U} \tag{25}$$

The vibrational coupling factor is obtained from the expression

$$V_{v_i} = \frac{Q(T_t)}{Q(T_{v_i})} \cdot \frac{Q(T_{f_i})}{Q(-U)} \tag{26}$$

where the partition function itself is defined as

$$Q(T) = \frac{1 - \exp(-N\theta/T)}{1 - \exp(-\theta/T)} \tag{27}$$

evaluated at the appropriate temperature. The negative quantity $(-U)$ can be considered as the "vibrational temperature" at which the molecules are formed by recombination in Treanor's preferential dissociation model. For the limiting case of $U = \infty$, the problem reverts to the nonpreferential model in which there is an equal probability of dissociation from any vibrational energy level.

It is assumed throughout this analysis that the usual equilibrium relationship between the forward and backward rate constants, as defined below, still applies. Note, however, that each term is based solely on the translational temperature.

$$K_{eq_k}(Tt) = \frac{Kf_k(Tt)}{Kb_k(Tt)} \qquad (28)$$

The terms $Ev_{i,\infty}$, Ev_i, and $Ev_{k,i}$ are obtained from an evaluation of the energy expression for the cut-off harmonic oscillator shown below using the temperatures Tt, Tv_i, and Tf_i, respectively.

$$Ev_i(T) = \epsilon v_i m_i w_i = m_i R\left[\frac{\theta_i}{\exp(\theta_i/T)-1} - \frac{N_i\theta_i}{\exp(N_i\theta_i/T)-1}\right] \qquad (29)$$

The term $Gv_{k,i}$ in Equation (8) is also obtained from Equation (29) by setting $T=-U$. For monatomic species $Ev_i = Ev_{i,\infty} = Ev_{k,i} = Gv_{k,i} = 0$, and $Vv_i = 1$.

For reactions in the chemical model that are basically not of the dissociation-recombination type, it may be necessary to evaluate $Ev_{k,i}$ and $Gv_{k,i}$ by other means than Equation (29). The preliminary results of a study designed to obtain the best values for $Ev_{k,i}$ and $Gv_{k,i}$ are presented for the Bortner chemical model in Tables VI and VII. Reactions which result in the net breaking of a molecular bond are presumed to involve a molecular species having an $Ev_{k,i}$ and $Gv_{k,i}$ term and a non-zero $fv_{k,i}$ or $bv_{k,i}$. The derivation of $Gv_{k,i}$ given in Reference 2 appears valid for the reaction $A_2 + X +$ energy $\rightleftharpoons 2A + X$ even for chemical and thermodynamic nonequilibrium. An exception to this rule is made for reactions in which a molecular bond is broken in an exothermic reaction. This effect is observed in, for example, the reaction

$$N + N + 5.8ev \rightleftharpoons N_2^+ + e^-$$

Engineering judgement would indicate that for these cases, set

Table VI. Vibrational Dissociation

Species i	Reaction k 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1) N_2	0	$\tilde{E}_{v_1}$	$\tilde{E}_{v_1}$	0	0	E_{v_1}	E_{v_1}	E_{v_1}	E_{v_1}	E_{v_1}	0	0	0	0	0	0	0	0	0	0
2) O_2	$\tilde{E}_{v_2}$	0	0	0	E_{v_2}	0	E_{v_2}	0	0	0	E_{v_2}	E_{v_2}	E_{v_2}	0	0	0	0	0	0	0
3) NO	0	0	0	E_{v_3}	E_{v_3}	E_{v_3}	E_{v_3}	0	0	0	0	0	0	E_{v_3}	E_{v_3}	0	0	0	0	0
4) NO^+	0	0	0	0	0	0	0	0	0	0	0	0	0	E_{v_4}	E_{v_4}	0	0	0	0	Ev
5) N_2^+	0	0	0	0	0	0	0	E_{v_5}	E_{v_5}	E_{v_5}	0	0	0	0	0	0	0	0	0	0
6) O_2^+	0	0	0	0	0	0	0	0	0	0	E_{v_6}	E_{v_6}	E_{v_6}	0	0	0	0	0	0	0
7) O_2^-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8) ↓ 14)	ATOMIC SPECIES, NO VIBRATIONA																			

Table VII. Vibrational Dissocia

Species i	Reaction k 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1) N_2	0	$\tilde{E}_{v_1}$	$\tilde{E}_{v}$	0	0	$E_{v_{1,eq}}$	$E_{v_{1,eq}}$	E_{v_1}	E_{v_1}	E_{v_1}	0	0	0	0	0	0	0	0	0	0
2) O_2	$\tilde{E}_{v_2}$	0	0	0	$E_{v_{2,eq}}$	0	$E_{v_{2,eq}}$	0	0	0	E_{v_2}	E_{v_2}	E_{v_2}	0	0	0	0	0	0	0
3) NO	0	0	0	$E_{v_{3,eq}}$	$E_{v_{3,eq}}$	$E_{v_{3,eq}}$	$E_{v_{3,eq}}$	0	0	0	0	0	0	E_{v_3}	E_{v_3}	0	0	0	0	0
4) NO^+	0	0	0	0	0	0	0	0	0	0	0	0	0	E_{v_4}	E_{v_4}	0	0	0	0	Ev
5) N_2^+	0	0	0	0	0	0	0	E_{v_5}	E_{v_5}	E_{v_5}	0	0	0	0	0	0	0	0	0	0
6) O_2^+	0	0	0	0	0	0	0	0	0	0	E_{v_6}	E_{v_6}	E_{v_6}	0	0	0	0	0	0	0
7) O_2^-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8) ↓ 14)	ATOMIC SPECIES, NO VIBRATIONA																			

VI. Vibrational Dissociation Energy Terms, $\bar{E}v_{k,i}$

Reaction k

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
0	0	0	0	0	0	0	0	0	0	E_{v_1}	0	E_{v_1}	E_{v_1}	0	0	0	E_{v_1}	0	E_{v_1}	0	0	0	0	0
E_{v_2}	0	0	0	0	0	C	0	0	0	0	0	E_{v_2}	0	E_{v_2}	E_{v_2}	0	0	E_{v_2}	0	0	E_{v_2}	0	E_{v_2}	E_{v_2}
0	E_{v_3}	E_{v_3}	0	0	0	0	0	0	0	0	0	0	E_{v_3}	0	0	E_{v_3}	0	E_{v_3}	E_{v_3}	0	0	0	0	0
0	E_{v_4}	E_{v_4}	0	0	0	0	E_{v_4}	0	0	0	E_{v_4}	0	E_{v_4}	E_{v_4}	0	E_{v_4}	E_{v_4}	E_{v_4}	E_{v_4}	E_{v_4}	0	0	0	0
0	0	0	0	0	0	0	0	0	E_{v_5}	E_{v_5}	E_{v_5}	E_{v_5}	E_{v_5}	0	0	0	0	0	0	0	0	0	0	0
E_{v_6}	0	0	0	0	0	0	0	E_{v_6}	0	0	0	E_{v_6}	0	0	E_{v_6}	0	0	E_{v_6}	E_{v_6}	E_{v_6}	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	E_{v_7}	0	0	E_{v_7}

ATOMIC SPECIES, NO VIBRATIONAL ENERGY

Table VII. Vibrational Dissociation Energy Terms, $\tilde{E}v_{k,i}$

Reaction k

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
[illegible]	0	0	0	0	0	0	0	0	0	E_{v_1}	0	E_{v_1}	E_{v_1}	0	0	0	E_{v_1}	0	E_{v_1}	0	0	0	0	0
E_{v_2}	0	0	0	0	0	0	0	0	0	0	0	E_{v_2}	0	E_{v_2}	E_{v_2}	0	0	E_{v_2}	0	0	E_{v_2}	0	E_{v_2}	E_{v_2}
[illegible]	E_{v_3}	E_{v_3}	0	0	0	0	0	0	0	0	0	0	E_{v_3}	0	0	E_{v_3}	0	E_{v_3}	E_{v_3}	0	0	0	0	0
[illegible]	E_{v_4}	E_{v_4}	0	0	0	0	E_{v_4}	0	0	0	E_{v_4}	0	E_{v_4}	E_{v_4}	0	E_{v_4}	E_{v_4}	E_{v_4}	E_{v_4}	E_{v_4}	0	0	0	0
[illegible]	0	0	0	0	0	0	0	0	E_{v_5}	E_{v_5}	E_{v_5}	E_{v_5}	E_{v_5}	0	0	0	0	0	0	0	0	0	0	0
E_{v_6}	0	0	0	0	0	0	0	E_{v_6}	0	0	0	E_{v_6}	0	0	E_{v_6}	0	0	E_{v_6}	E_{v_6}	E_{v_6}	0	0	0	0
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	E_{v_7}	0	0	E_{v_7}

ATOMIC SPECIES, NO VIBRATIONAL ENERGY

2

$$\bar{E}v_{k,i} = Ev_i$$
$$\bar{G}v_{k,i} = Ev_{i,\infty}$$
$$fv_{k,i} = bv_{k,i} = 0$$

Reactions in which there is no net breaking of a chemical bond, but in which an atom exchange process occurs, are stated in Reference 11 to be very effective in exciting vibrational energy. The shuffle reactions, for example,

$$O + NO \rightleftharpoons N + O_2$$
$$O + N_2 \rightleftharpoons N + NO$$

are believed to have a strong effect on vibrational excitation of the species N_2, O_2, and NO. To account for this effect on these molecular species set

$$\bar{E}v_{k,i} = Ev_i$$
$$\bar{G}v_{k,i} = Ev_{i,\infty}$$
$$fv_{k,i} = bv_{k,i} = 0$$

Reactions in which a molecular species gains or loses an electron without a net breaking of a molecular bond are presumed to have no vibrational coupling effects. For molecular species in these reactions, set

$$\bar{E}v_{k,i} = Ev_i$$
$$\bar{G}v_{k,i} = Ev_i$$
$$fv_{k,i} = bv_{k,i} = 0$$

The exponents $fv_{k,i}$ and $bv_{k,i}$ are also set equal to zero under any of the following additional cases,

1. The specie does not enter into the reaction except possibly as a catalytic species,

2. The speciesis monatomic,

3. It is desired to set the coupling factor equal to 1 without changing the calculation of Vv_i.

The present set of exponents, $f_{v_{n,i}}$ and $f_{v_{k,i}}$ for the Bortner chemical model are listed below for all non-zero values.

$$f_{v_{2,1}} = 1$$

$$f_{v_{3,1}} = 1$$

$$f_{v_{1,2}} = 1$$

One remaining term in Equation (8) that requires defining is the vibrational relaxation time, $\tau_{v_{i_m}}$. Since each vibrating species can conceivably collide with every species included in the model, it is necessary to find a weighted value of τ_{v_i} which represents the entire gaseous mixture. The relationship for this weighted value, $\tau_{v_{i_m}}$, is given by:

$$\frac{1}{\tau_{v_{i_m}}} = \frac{X_A}{\tau_{v_{A(P_{TOT})}}} + \frac{X_B}{\tau_{v_{B(P_{TOT})}}} + \frac{X_C}{\tau_{v_{C(P_{TOT})}}} + \cdots \tag{30}$$

The derivation of this expression is presented in Appendix II and the individual relaxation times, τ_{v_A}, τ_{v_B}, etc., are obtained from the following equation, taken from Reference 12.

$$\tau_{v_N} = \frac{1.013\times10^{6}}{P_{TOT}} \exp\left[1.16\times10^{-3}\mu_{N-M}^{1/2}\Theta_N^{4/3}\left(T_t^{-1/3} - 0.015\mu_{N-M}^{1/4}\right) - 18.42\right] \tag{31}$$

where P_{TOT} is the total pressure for the entire system and not the partial pressure of any one constituent.

It has been found experimentally, References 13, and 14, that the vibrational relaxation time constant for expansion flows in a supersonic nozzle is much less than is predicted from the above equation which correlates measurements of the relaxation to equilibrium behind shock waves. Since the explanation of this effect is not known it is recommended that the time constants computed for the above equation be decreased by a factor of 15 for nozzle expansion type flows.

6. ELECTRONIC RELAXATION EVALUATION

The electronic energy level of a molecule can change due to the absorption or emission of a photon or by various types of inelastic collisions with other particles: neutral molecules, either in their ground states or in excited states, and free electrons. The rate at which electronic relaxation takes place depends upon the numbers of the different species present and the probabilities of each type of inelastic collision. It is thus coupled to all the other relaxation processes, in principle.

Attempts to describe electronic relaxation have resorted, of necessity, to various assumptions and simplifications. One of the more common ones is that the population of electronic levels is Boltzmann-like.

$$N_l/N = g_l \exp(-EL_l/T_e) \Big/ \sum_l g_l \exp(-EL_l/T_e) \qquad (32)$$

The electronic temperature T_e can be regarded simply as a convenient parameter with which to describe the distribution of electronic energy.

Allen, et al. (Ref. 15) measured the intensity of radiation, I, in the 0.55 to 1.0 μ region during the passage of nitrogen shocks and found that I/I eq peaked a short distance behind the shock and then decayed to unity (equilibrium). The parameter (time to peak intensity) X (initial pressure of unshocked gas) correlated with shock velocity. Time to peak also correlated with the <u>vibrational</u> relaxation time for nitrogen. The observed radiation behavior was compared with the calculated radiation from the nitrogen "first positive" band which radiates in the measured wavelength region. The calculations assumed that T_e was equal to translational temperature. It was found that observed and calculated radiation curves agreed during the later stages of relaxation, but not initially. These results were interpreted as suggesting that electronic temperature remained in equilibrium with vibrational temperature and that both approached the translational temperature after the radiation peak.

It was also found that the time to peak radiation obeyed the law $t_p p = f(U_s)$. This implies that the electronic relaxation depends on binary collisions (because of the pressure dependence) and that the effective relaxation constant is a function of the translational temperature, at least in the initial stages (since the initial translational temperature is a function of shock speed). This kind of behavior could result if there was strong coupling between vibrational and electronic energies, since the vibrational relaxation time behaves in this way (Ref. 12).

Later, Allen (Ref. 16) made simultaneous radiation intensity measurements on shock heated nitrogen in different wavelength regions with a resolution of 5A and determined the rotational, vibrational, and electronic temperatures separately by using nitrogen itself as the thermometric substance. The rotational structure was not resolved but the band shape for the N_2^+ "first negative" system was used to deduce T_r. The relative band intensities of the same system were used to obtain T_v. The radiation over the range 0.55 to 1.1 μ was used to deduce the electronic temperature from the N_2 "first positive" band system. The results, for a shock speed of 6.4 mm/μ sec, show the electronic temperature rising more rapidly than the vibrational temperature. T_e was found to peak (at the time corresponding to peak radiation intensity) and then to relax downward toward the equilibrium temperature without ever reaching the translational temperature. These measurements imply that electronic temperature is not coupled with vibrational temperature. Furthermore, the results cannot be explained in terms of a simple relaxation equation of the form,

$$u_s \frac{d\epsilon_e}{ds} = \frac{\epsilon_e(T_t) - \epsilon_e}{\tau_e(T_t)} \qquad (33)$$

where,

$\tau_e(T_t)$ = relaxation time, assumed a function of T_t.

This is because the electronic temperature peaks and begins to fall while still below the translational temperature.

It should be emphasized that not all of the temperatures were determined from the same species. There is no a priori reason for expecting the internal energy modes of N_2 and N_2^+ to be in equilibrium, however much this would simplify the situation.

Hansen and Chapin (Ref. 17) reach similar conclusions from an analysis of the total gas cap radiation from small spheres fired through air in a ballistic range. They compared experimental values of total radiation intensity with radiation calculated according to three different assumptions:

1. $T_e = T_t$

2. $T_e = T_v$

3. The population of excited electronic states rate-determined by two-body collisions with neutrals and with electrons, the latter collision being much more efficient.

For the third type of calculation it was necessary to introduce rate constants for electronic excitation which were merely plausible estimates.

It was found that assumption 1 overestimates the observed radiation by several orders of magnitude. Assumption 2 gave closer agreement, but showed the wrong pressure dependence. Assumption 3 gave reasonable agreement over the range u_s = 14,000 - 22,000 ft/sec, p = 1 - 100 mm Hg. The calculated effective electronic temperatures (for assumption 3) were different for each species but gave qualitatively similar histories, namely, electronic temperatures rising more rapidly than vibrational temperature, but peaking before reaching the (higher) translational temperature.

Available wind tunnel information on electronic relaxation gives a somewhat different picture. McGregor and Brewer (Ref. 18) carried out simultaneous measurements of electronic excitation temperature T_e (as determined spectroscopically from Equation (32)) and free electron translational temperature T_{el} (as measured by an electrostatic probe) in a low density Argon free jet. Here, both T_e and T_{el} were out of equilibrium throughout the entire flow field. It was found that T_e and T_{el} agreed within 3% and that both were a factor of three higher than the bulk temperature of the neutral Argon atoms.

The role of the free electron is brought out by the work of Hurle and Russo (Ref. 14). They measured the sodium atom excitation temperature T_{Na} in Argon and 1% N_2-Argon during expansion in a wind tunnel nozzle. They found that for pure Argon, the temperature T_{Na} remained frozen at a value corresponding to the calculated Argon translational temperature at the throat. When 1% N_2 was added T_{Na} dropped appreciably and agreed with the calculated N_2 vibrational temperature, T_V.

The authors of Reference 14 explain these results as follows: The N_2 vibrational temperature is influenced primarily by collisions with neutral molecules and relaxes at a rate which is 15 times faster than would be predicted from shock tube relaxation data. Vibrationally excited N_2 is very effective at exchanging energy with free electrons and the latter take up a temperature $T_{el} \approx T_V$. The free electrons, in turn, are very effective (in comparison with neutrals) at exchanging energy with sodium atoms so that T_{Na} approaches T_{el}. The only measured quantity, of course, is T_{Na}.

The significance of free electrons is also brought out by Morgan and Morrison (Ref. 19). They make estimates of the relative electronic excitation efficiencies of free electron and neutral collisions and find that the former is orders of magnitude higher. They conclude that immediately behind the shock electronic excitation and subsequent ionization take place by neutral collisions only. However, when the electron fraction rises to a value of the order of 10^{-4}, electron collisions become the dominant mechanism for both excitation and ionization.

The explanations given in the references cited above are in conflict and do not provide a basis for the rational selection of an electronic relaxation model. It was decided to approach the problem by a re-analysis of the nitrogen shock data from Reference 15, using the computer program developed under this contract as a working tool. Nitrogen was chosen because of its relatively simple chemistry and because it forms the major constituent of air. The work consisted of three parts:

1. Computation of the apparent T_e variation behind nitrogen shock waves, based upon a consistent calculation of the chemical and vibrational rates, and a comparison between experimental and theoretically calculated radiation histories.

2. Formulation of a plausible electronic relaxation model consistent with the T_e variation found in part 1, including a numerical estimate of the rate constant.

3. Confirmation of the model by recalculating composition and histories using the relaxation rate expression developed in part 2.

The shock conditions of Reference 15 are given in Table VIII. They were calculated from measured parameters using the ideal gas approximation with $\gamma = 1.4$ (nitrogen behind the shock is assumed to have $T_t = T_e$). It was further assumed for simplicity that the velocity ratio across the shock had the limiting hypersonic value 1/6. Initial temperature (not stated in Reference 15 but presumably room temperature) was taken to be 300°K.

Table VIII. Nitrogen Shock Conditions (Before Relaxation)

Parameter	Case 1	Case 2
Shock speed (mm/μ sec)	4.98	5.34
Initial pressure (mm)	10.0	3.00
Temperature behind shock (°K)	12,000	13,700
Pressure behind shock (dynes/cm^2)	3.19×10^6	1.09×10^6
Mass flow per unit area (gm/cm^2 sec)	7.47	2.40

Since electronic excitation was the factor to be found, electronic energy must be approximated in these calculations. This was done by assuming $T_e = T_v(N_2)$. Because of the small amount of energy tied up as electronic energy for the conditions in question, this approximation should have little influence on the composition and translational temperature history.

A nonequilibrium flow field calculation was carried out for both of the shock conditions listed in Table VIII using the area matching option. The calculation yielded translational temperature T_t, vibration temperature T_v, density ρ, and the concentrations of N_2, N_2^+, N, N^+, and e^- as a function of distance behind the shock.

For each shock speed, theoretical values of radiation intensity in the 0.5 to 1.0 micron region were calculated at a series of locations behind the shock. At each location, several values of intensity were calculated, based on parametric variations of the electronic temperature over the expected range. The radiation calculations were carried out using a program RADIAT, developed by North American Aviation (Reference 20). This program is designed to give spectral and total radiation intensities (integrated over a finite wavelength range) for gas mixtures as a function of temperature, density, and composition of the radiating species. The program was designed to compute radiation for equilibrium gas mixtures, that is, where $T_t = T_v = T_e$. However, the above temperatures merely determine the population of species in each electronic and vibrational level. Therefore, emitted radiation intensity for molecular band systems will be correctly evaluated when the input temperature is set equal to $T_v = T_e$ even when $T_t \neq T_e$.

Hansen (Ref. 21) has shown that when $T_v \neq T_e$ the spectral intensity from molecular radiators is altered. However, an inspection of his results indicates that the integrated radiation over a major portion of any vibrational-electronic band should give results which are insensitive to T_v.

Figure 3 shows a sample output from RADIAT. The program calculates separately the spectral contributions from the first and second positive bands

ABSORPTION COEFFICIENTS OF GASES (/CM) T= 8000.K RHO= 0.12E 00 ATM
I (TOTAL)= 8.042E 00 WATTS/SQ.CM.-STER S = 1.0000E 00 CM
UNITS OF I (NU) ARE 'WATTS-MICRON/SQ.CM.-STER'

NU(/MICRON)	N2(1+)	N2(2+)	N2+(1-	N(PE)	EFF	TOTAL	I (NU)
POPULATION	0.385E-03	0.102E-03	0.104E-04	0.113E 00	0.159E-04	0.000E-38	0.000E-38
1.05000	1.310E-03	4.245E-09	9.645E-08	0.000E-39	3.372E-09	1.310E-03	3.217E 00
1.15000	5.821E-03	1.373E-08	2.977E-07	0.000E-39	2.565E-09	5.821E-03	1.521E 01
1.25000	3.001E-03	2.627E-08	9.091E-07	5.809E-07	1.996E-09	3.003E-03	8.234E 00
1.35000	5.021E-03	1.166E-07	1.140E-06	1.392E-06	1.584E-09	5.024E-03	1.421E 01
1.45000	2.984E-03	2.281E-07	3.022E-06	1.123E-06	1.278E-09	2.989E-03	8.620E 00
1.55000	3.737E-03	7.285E-07	1.020E-05	9.190E-07	1.046E-09	3.749E-03	1.089E 01
1.65000	2.775E-03	1.603E-06	8.448E-06	7.617E-07	8.666E-10	2.786E-03	8.069E 00
1.75000	1.622E-03	4.983E-06	3.914E-05	7.239E-07	7.262E-10	1.667E-03	4.773E 00
1.85000	1.517E-03	1.103E-05	3.800E-05	7.825E-07	6.146E-10	1.567E-03	4.395E 00
1.95000	8.659E-04	1.926E-05	1.419E-04	6.681E-07	5.247E-10	1.028E-03	2.804E 00

Figure 3. Sample Output from Radiation Computer Program

of N_2 , the first negative band of N_2^+, the photoelectric continuum of nitrogen atoms, and the free-free radiation from electrons. In all cases the first positive band radiation was found to be dominant for the cases analyzed.

The absolute radiation intensities calculated in this way were divided by the theoretical radiation at equilibrium (based upon extrapolated compositions and translational temperature) to obtain a series of theoretical values of I/I eq corresponding to various distances behind the shock and to various assumed values of T_e.

Experimental values of the relative integrated radiation intensity I/I eq in the region dominated by the N_2 "first positive" band system are given in Reference 15. The wavelength ranges are slightly different in the two cases: 0.55 - 1.1 microns for $u_s = 4.98$ mm/μ sec and 0.55 - 1.0 microns for $u_s = 5.34$ mm/μ sec. This is not expected to make a significant difference for the present purpose.

A comparison of the calculated and experimental radiation data yielded a series of T_e values for which the two agreed. The results, for the lower shock speed, are given in Figure 4, together with calculated values of translational and vibrational temperatures.

The results were somewhat surprising. The calculated vibrational temperature rose much more rapidly than the electronic temperature and peaked much earlier (not shown in Figure 4). The electronic temperature continued to rise until it reached the translational temperature (or perhaps the vibrational temperature, since both were very close together at that point).

Tentatively the following form of the relaxation rate law was assumed:

$$u \frac{d\epsilon_e}{ds} = \frac{\epsilon_e(T_t) - \epsilon_e}{\tau_{e_1}(T_t, p)} + \frac{\epsilon_e(T_v) - \epsilon_e}{\tau_{e_2}(T_v, p_{el})} \qquad (34)$$

where $\tau_{e_1}(T_t, p)$ is a relaxation time characteristic of neutral collisions

p is pressure of neutrals (essentially total pressure)

p_{el} is pressure of electrons

$\tau_{e_2}(T_v, p_{el})$ is a relaxation time characteristic of electron collisions

Such an expression would describe an electronic relaxation which tracks the translational temperature during the early stages when electron concentration is very low and then tracks vibrational temperature in the later stages because of the electron's much greater excitation cross section. Since electron concentration was very low ($\sim 3 \times 10^{-5}$ mole fraction) in the low speed case, it was decided to attempt a fit using only the first term of Equation (34).

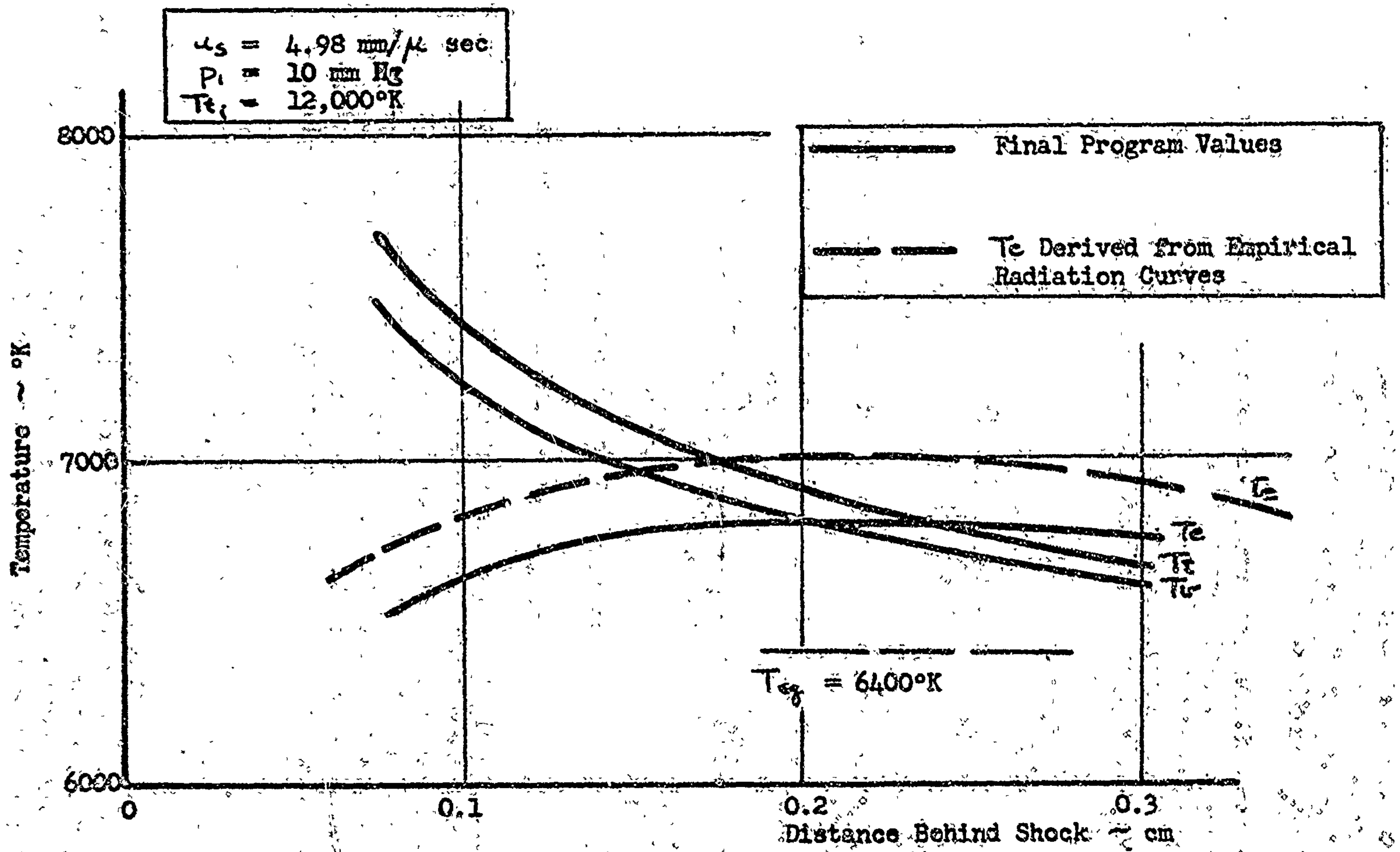


Figure 4. Temperature Histories for a Pure N_2 Shock

Even with this simplification, there were further difficulties. The empirical radiation data (and therefore the empirical T_e curves) were not resolved for very short distances behind the shock. Also, the relaxation time constant must be regarded as an unknown function of quantities which vary throughout the shock.

These difficulties were met by assuming first that the electronic time constant was inversely proportional to pressure (as is the vibrational time constant) and second, that the product $p\tau_e$ was a rather weak function of T_t which could be adequately represented by an average value over a range of a few thousand degrees. With these approximations Equation (34) could be written

$$\frac{d\epsilon_e}{ds} = \frac{p}{u\,(\overline{\tau_e p})}\left[\epsilon_e(T_t) - \epsilon_e\right] \tag{35}$$

and integrated from the first point at which empirical T_e data was obtained up to peak:

$$(\overline{\tau_e p}) = \frac{p}{u\,(\epsilon_{e_{M}} - \epsilon_{e_i})}\int_{S_{init}}^{S_{Max.}}\left[\epsilon_e(T_t) - \epsilon_e\right] ds \tag{36}$$

where $\epsilon_{e\,Max.}$ is the electronic energy at peak

$\epsilon_{e\,init.}$ is the initial electronic energy

The numerical integration implied by Equation (36) was carried out for both shock cases listed in Table VIII, yielding average τp values at effective translation temperatures of 7480°K and 9970°K, respectively. They are ...m in Figure 5, together with the corresponding vibrational time constant for N_2 as calculated by Equation (31). Although there was little basis for an adequate estimate of temperature dependence, the results were fitted to an equation similar to the vibration equation in form to yield

$$(\tau_e p)_{N_2} = 9.23 \times 10^{-8} \exp\left[103.7/T_t^{1/3}\right] \tag{37}$$

Equation (37) was then used in a recalculation of the lower speed shock case. Again, the results were surprising. It was discovered that Equation (37) grossly overestimated the initial rate-of-rise of the electronic temperature. The behavior near peak was qualitatively correct but peak temperature was displaced upward and closer to the shock front.

It was concluded that even though the electron concentrations were very low, the second term in Equation (34) was important. The relaxation rate data were re-interpreted in this way by equating rates at the peak electronic

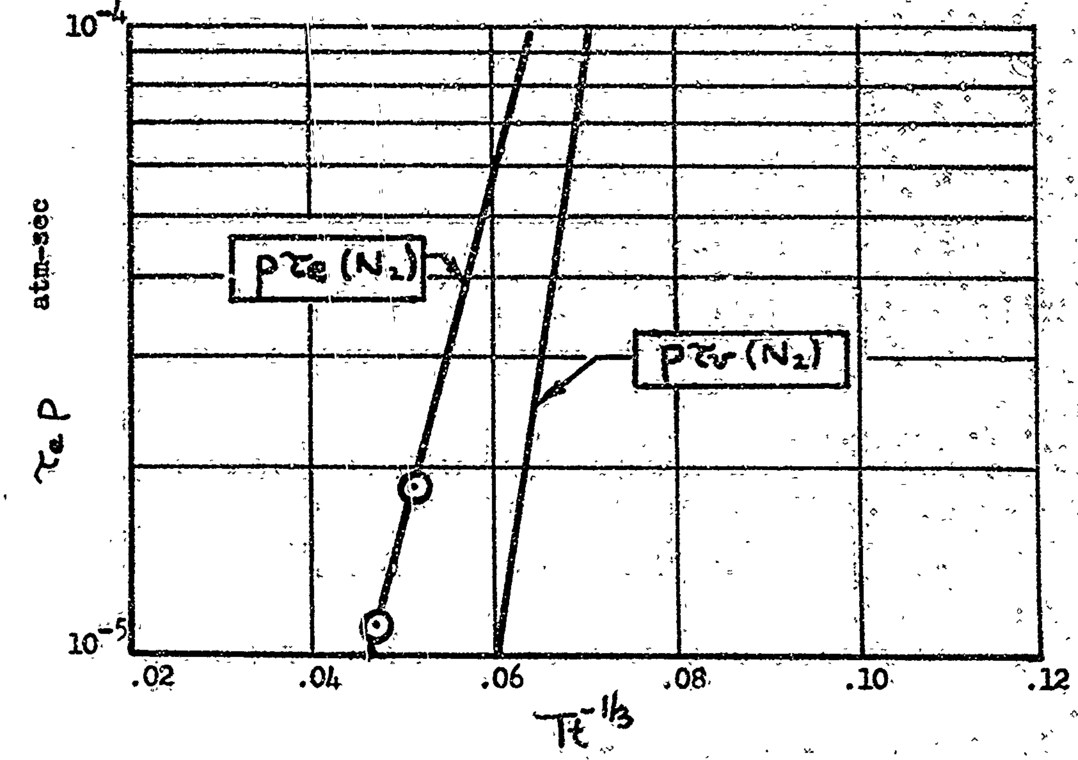


Figure 5. Apparent Electronic Relaxation Time Constants

temperature. The new trial model becomes

$$u \frac{d\epsilon_e}{ds} = \frac{\epsilon_e(T_v) - \epsilon_e}{\tau_e(T_v, p_{el})} \tag{38}$$

where

$$\tau_e p_{el} = 2.92\times10^{-12} \exp\left[103.7/T_t^{1/3}\right] \tag{39}$$

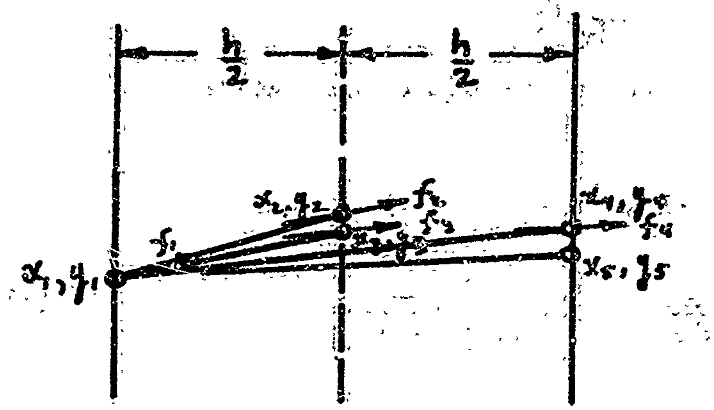
The results of a final trial calculation using Equation (38) are also shown in Figure 4 (T_v and T_t remained essentially unchanged for all trial calculations). The results agree very closely with empirical electronic temperature. This result appears consistent with the interpretations of Reference 14 that electronic temperature is excited by the action of electrons and that the potential causing relaxation is governed by the vibrational temperature of nitrogen molecules.

It should be recognized that the results of this part of the study are very limited. They apply to only a small range of shock speeds and for one type of chemistry. Moreover, the suggested temperature dependence is very speculative at this time. Much more work is required to extend the model and the associated rate data to the ranges of temperature and composition needed for hypersonic flight and wind tunnel test interpretation.

7. INTEGRATION PROCEDURE

The old version of the nonequilibrium program employed a fourth order Runge-Kutta integration scheme modified for the Gill correction. Treanor, Reference 5 , has indicated that this scheme can be unseconomical to use in regions of the flow field where the rate of a parameter in a highly coupled system is extremely sensitive to slight displacements of its integrated value from the true curve. In Reference 5 , Treanor defines a method for alleviating this sensitive situation and permitting a larger step size to be used in the integration process. When the rates are not sensitive to the local values, the new integration scheme becomes equivalent to the original Runge-Kutta procedure.

A brief description, summarizing the calculation required in Treanor's method, is furnished below. The process of integrating from one station to another in the flow field is carried out in four basic steps. The integration interval, h , is divided in half and the four basic steps pertain to two calculations at each half step as illustrated in Figure 6 below.



x = distance along streamline (independent variable)

y = flow parameter, specie concentration, vibrational energy (dependent variable)

f = derivative of y with respect to x, dy/dx

Figure 6. Illustration of Runge-Kutta Integration Scheme

<u>First Cycle (First Half Interval)</u>

<u>Step 1</u> - Knowing x_1, y_1, and f_1, compute x_2 and y_2 from

$$x_2 = x_1 + \frac{h}{2}$$

$$y_2 = y_1 + \frac{h}{2} f_1$$

<u>Step 2</u> - Using x_2 and y_2, evaluate f_2. The method of evaluating the derivatives was described in an earlier section.

Second Cycle (First Half Interval)

Step 1 - Knowing x_1, y_1, and f_2, compute x_3 and y_3 from

$$x_3 = x_1 + \frac{h}{2}$$

$$y_3 = x_1 + \frac{h}{2} f_2$$

Step 2 - Using x_3 and y_3, evaluate f_3.

Step 3 - Determine P from the following relationship:

$$P = -\left(\frac{f_3 - f_2}{y_3 - y_2}\right)$$

Step 4 - Determine F_1 and F_2 from the relationship:

$$F_1 = \frac{e^{-Ph} - 1}{-Ph}$$

$$F_2 = \frac{(e^{-Ph} - 1) + Ph}{(Ph)^2}$$

First Cycle (Second Half Interval)

Step 1 - Using h, y_1, f_1, f_2, f_3, P, F_1, and F_2, determine y_4 from

$$y_4 = y_1 + h\left\{2f_3F_2 + f_1(F_1 - 2F_2) + f_2(Ph)F_2\right\}$$

Step 2 - Determine x_4 from

$$x_4 = x_1 + h$$

Step 3 - Use x_4 and y_4 to evaluate f_4.

Second Cycle (Second Half Interval)

Step 1 - Compute F_3 from the relationship

$$F_3 = \frac{F_2 - \frac{1}{2}}{-Ph}$$

Step 2 - Compute y_5 from the relationship:

$$\begin{aligned} y_5 = y_1 + h\Big\{ & f_1F_1 + \big[-3(f_1 + Py_1) + 2(f_2 + Py_2) + 2(f_3 + Py_3) \\ & - (f_4 + Py_4)\big]F_2 + 4\big[(f_1 + Py_1) - (f_2 + Py_2) \\ & - (f_3 + Py_3) + (f_4 + Py_4)\big] \end{aligned}$$

Step 9 - Compute $x_5 = x_1 + h$.

This completes the integration cycle for the current interval and the process is repeated for each succeeding interval downstream. Note that point 5 is identical to point 1 for the next interval.

The integration step size is determined in part from the "stiffness" parameter, P, as defined in Step 3 for the second cycle in the first half interval. Treanor states that the integration procedure will be stable for positive values of P so long as the value of $Ph \cong 75$. For negative P the Treanor scheme is inferior to the Runge-Kutta method and the program should automatically resort to the Runge-Kutta method using an appropriately reduced step size criteria of $Ph \cong 5$. It has been found that under certain conditions step size is greatly overestimated when it is based solely on the stiffness parameter. In addition, it has been found possible for the intermediate values at points 2, 3, and 4 to be negative. To ensure a foolproof integration a second test is made on the parameter

$$\frac{fh}{y}$$

Local values of f and y are used at points 1, 2, and 3. This test is used to set the original step size estimate using values at point 1. Step size is selected to set the value of the parameter exactly to the nominal value as listed in Table IX provided the step size does not increase more than a limiting value. The following tests are allowed to only reduce step size as indicated. No increase is permitted. A second test of the parameter is made as soon as properties and derivatives are found at point 2, where only an upper bound is used. Step size is reduced by successive corrections based on 10% of the indicated step size error (using the nominal values) until the test is passed. The integration now computes properties and derivatives at point 3. The Ph test is first applied at this point, using 50% of the indicated step size correction (using the nominal value) to place Ph below the upper bound. Prior to making the Ph test a check is made of all parameters to see that y_2 and y_3 (the terms in the denominator of the Ph test) do not differ by less than 30 in the seventh and eighth significant figures. If the difference is less than 30, that parameter is dropped temporarily from the Ph test because of the good possibility that it may prove highly inaccurate and produce an erroneous reading of integration instability. The

$$\frac{fh}{y}$$

parameter is applied as before to possibly further reduce step size. If the upper bound is not exceeded, the integration for this interval is completed until values at point 5 are found. These values become the initial values for the next integration interval and the procedure is repeated.

It has been found desireable to put a limit on the increase between step sizes for adjacent intervals. The computer program now uses a limiting increase of 10%, however, the RAM B3 sample cases used a limiting increase of 100%. The RAM B3 sample cases were also run with the upper bound and nominal values of the Runge-Kutta Ph parameter set to 10.0 and 8.0. Experience with the nozzle flow case proved the desireability of using the lower values to reduce the variation of step size over a number of integrations.

Table IX. Criteria for Integration Stability Tests

Test Number	Parameter	Upper Bound	Nominal Value	Lower Bound
1	$f_1 h/y_1$	0.6	0.5	0.4
2	$f_2 h/y_2$	0.6	0.5	—
3a	Ph (Treanor)	30.0	25.0	—
	Ph (Runge-Kutta)	7.0	6.0	—
3b	$f_3 h/y_3$	0.8	0.5	—

SECTION III

COMPUTER PROGRAM DEVELOPMENT

This section describes the operating characteristics of the program; presents a flow diagram of the main program; and describes the program input and output. An input storage location map is also included to aid in the preparation of input data sheets.

1. OPERATING ENVIRONMENT

The program was developed and checked out on the IBM 7094 computer system at the Space Division Computing Center. The program was written in FORTRAN IV language and compiled with IBM's FORTRAN IV Compiler Program. A trial run with the program has been made on the existing IBM 7044/7094 direct-coupled digital computer system at Wright-Patterson AFB, Ohio, and the program proved compatible with their computer system with one exception. All unused spaces in the data field or input cards must either be filled in with zeros or a decimal point must be used in order for the read format statement to operate properly. Examples of this can be seen in the sample data sheets shown later in the text.

2. PROGRAM DESCRIPTION

The computer program consists of a main program and fourteen subprograms. In addition, certain library routines are also employed by the program.

A brief descriptive flow chart of the main program is presented in Figure 7 to illustrate the basic calling sequence of the subprograms. One can observe from Figure 7 that the program contains an initialization procedure and a cyclic process which consists of evaluating derivatives of certain flow field parameters and integrating these derivatives forwardly along a predetermined path to obtain a new set of properties. The completion of an integration interval requires cycling through the loop four times. On the fourth time through the loop the value of MK is altered from one to two and the program prints the flow field properties at the end of the integration interval. The program then checks to see if it should continue integrating or stop at its present location. The program is set up to evaluate the derivatives of all parameters for the start of the next integration interval on the fourth time through the loop. Thus, if it is to continue integrating, it need only return to the beginning of the loop and repeat the process. The initialization procedure at the start of the program consists of reading-in all input data, setting up certain working arrays, and computing derivatives of the integrated parameters at the starting point. The selection of a starting point will be discussed later in more detail.

The purpose of each subprogram is briefly discussed below. The subprogram BEGIN is responsible for reading-in all input data, establishing certain working tables and arrays, and writing-out the input data and

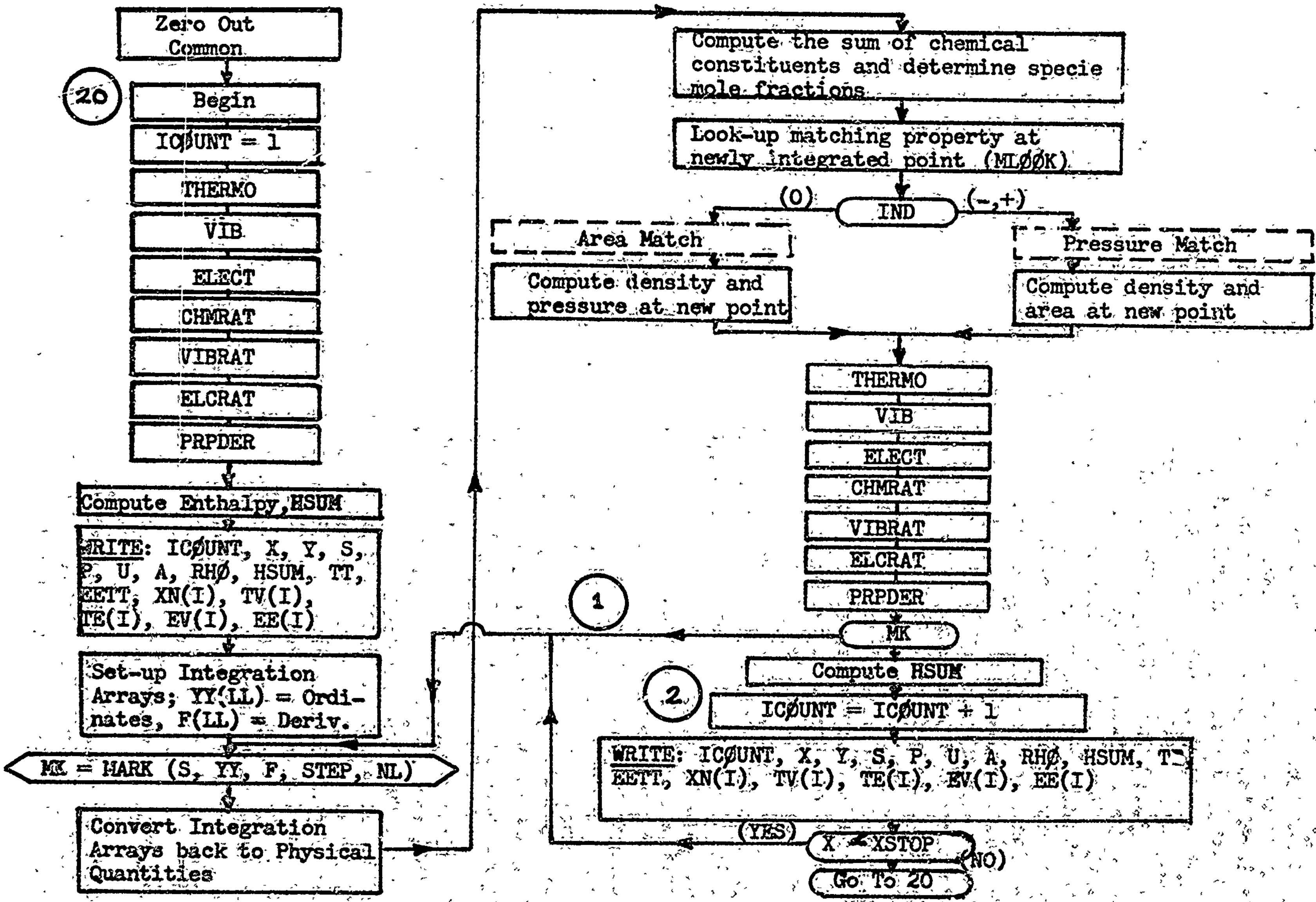


Figure 7 . Main Program Flow Chart

initial starting properties. The function of subprogram THERMO is to compute the thermodynamic properties, enthalpy and specific heat, for each chemical species as functions of the three temperatures T_t, T_{v_i}, and T_{e_i}. In addition, it evaluates the forward and backward chemical rate constants based solely on translational temperature. Subprogram VIB is basically concerned with computing individual terms used in evaluating the vibrational energy rates for the molecular species. The terms computed in this subprogram are $E_{v_{i,\infty}}$, E_{v_i}, G_{v_i}, $\bar{E}_{v_i}$, N_{v_i}, and τ_{v_i}. The subprogram ELECT is responsible for obtaining similar terms ($E_{e_{N_2}}$, E_{e_∞}, and $\tau_{e_{N_2}}$) used in the electronic rate expression for nitrogen. Subprogram CHMRAT has several functions. First, it applies the vibrational and electronic coupling factors to the forward and backward chemical rate constants computed in subprogram THERMO. These rate constants then become functions of T_t, T_{v_i}, and T_{e_i}. Second, it obtains the chemical formation and destruction terms for each species and at the same time combines these terms with the E_{v_i}, G_{v_i}, and $E_{v_{i\infty}}$ terms used in the vibrational rate expression. CHMRAT also combines the chemical formation and destruction terms used to form species net chemical rates which are integrated parameters in the program. Subprogram VIBRAT evaluates the vibrational energy rate, dh_{v_i}/ds, and the corresponding vibrational temperature rate, dT_{v_i}/ds, for each applicable molecular species. Subprogram ELCRAT is similar to VIBRAT in the sense that it evaluates the electronic energy rate, dh_e/ds, and the derivative of electronic temperature, dT_e/ds. The program is temporarily restricted to calculating the electronic derivatives for only the species, N_2. The last subprogram to be called in the derivative evaluation sequence is the subprogram PRPDER. This routine uses the previously calculated vibrational, electronic, and chemical rates in a general flow relationship for dT_t/ds. One final derivative, du/ds, is also evaluated in the subprogram PRPDER. Both of these derivatives are functions of the matching parameter which may be streamtube area or the pressure distribution along the streamtube. Subprogram MLØØK obtains the value of the matching parameter as a function of the local position along the streamtube. Since s is the independent variable in the analysis, local streamtube coordinates X and Y are obtained from the newly integrated value of s in this subprogram. The subprogram DERVP is called by PRPDER to obtain the derivative of the matching parameter. It uses a Lagrangian three-point fit to evaluate the derivative.

The final subprogram called is the function MARK. This subprogram is responsible for integrating the previously evaluated derivatives using a fourth-order Runge-Kutta integration procedure. It also contains an elaborate testing scheme, which was discussed in detail in a previous section of this report, for altering step-size while maintaining accuracy and control over the stability of the calculations. There are four branches within this subprogram; one for each portion of the half-cycle discussed in the theoretical section on the integration procedure. On the fourth time through the subprogram during each integration step, MK is changed from one to two signaling the completion of the integration procedure for that step and allowing the main program to be routed through the print statement.

3. OPERATING INSTRUCTIONS

There are several items which are pertinent to the proper operation of the program. For instance, the value of XSTOP, which is the point at which the program stops integrating, must lie within the tabulated matching

parameter data. It is also necessary to make the input values of the coordinates X and Y equal to first values of TABX and TABY and the flow property (pressure or area) equal to the first value of the matching parameter, TABAP. In this way, streamtube distance, S , always starts at zero.

If the print indicator LPRNT is set to zero, a limited printout of input data is obtained. This basically consists of input data that may change from case to case when the chemical model remains fixed. For example, each new case will have new starting point data and a new description of the matching point parameter with streamtube distance. On the other hand if LPRNT = 1, a full printout of all input data is obtained. Two other indicators that require an explanation are IND and UV. If IND = 0, streamtube area is used as the matching parameter. For a pressure match, IND is set equal to one. The indicator UV is used to signal the program to follow either the preferential or nonpreferential dissociation model derived by Treanor. The term nonpreferential applies to the fact that dissociation may occur at any energy level; whereas the term preferential applies to the case where dissociation occurs to a greater extent at the higher energy levels. The nonpreferential model is obtained when UV = 0.

The program is presently set up to handle a limited air model chemistry in line with the current AFFDL tunnel requirements. The species present in the model are N_2, O_2, NO, NO^+, N, O, e^-, and Ar. The reactions included in the current model, with reference to Tables IV and V, are 1, 2, 3, 4, 5, 6, 7, 14, 15, and 20. Obviously, one must always insure that there is compatibility between the species and reactions used in the program. The program has the provision for eliminating both species and reactions so long as this compatibility restriction is observed. Species are eliminated by setting their initial concentrations to zero; and reactions are eliminated by setting their forward stoichiometric coefficients to zero. Bortner gives two sets of chemical rate data, one for high temperature use where the reactions are basically endothermic and the other for low temperature use where the reactions are basically exothermic. The data for the program parameters FA, FB, FC, BA, BB, BC, and XMU, all pertaining to the evaluation of the chemical rates, must be changed depending on which case is involved.

There is a provision within the program for adjusting the vibrational time constant, TAUV, when a nozzle flow case is being considered. As stated in the theoretical section of this report, the vibrational time constant for nozzle flow has been observed to be about fifteen times smaller than that for external flow field studies. The input constant TAUADJ is used to adjust the time constant accordingly.

Initial starting conditions for the program will either be representative of a point immediately behind the shock in the case of external streamline flow or a point slightly downstream of the throat for the nozzle case. For the shock case, one assumes that translational temperature is immediately equilibrated and that the vibration and electronic temperatures remain equal to the free stream temperature. It is also assumed that chemical dissociation does not occur in passing through the shock. Therefore, the chemical composition is the same as for the free stream air. The remaining flow conditions are then established. For the nozzle case, the flow is assumed to be in thermal and chemical equilibrium and $M_{frozen} > 1$.

4. INPUT DATA

The input data to the program are entered according to the storage location map presented in Table X. All parameters identified with a single asterisk are basic input information to the program and generally remain constant except when modifications are made to the chemical model. The parameters marked with a double asterisk are also input and basically change from case to case. The FORTRAN symbols appearing in Table X are defined in the List of Abbreviations and Symbols at the beginning of this report.

A complete set of sample data sheets for the RAM-B3 streamline No. 5 is presented in Appendix III. Data sheets for the other streamline cases are presented in Appendixes IV-X, as changes to the input data for the streamline No. 5 case. The input data sheets for the nozzle case are presented in Appendix XI and differ from the RAM-B3 cases in that the low temperature chemical rate data are used.

The first card for each case consists of a set of integers which are indicators used in the program. This card must always be first. Thereafter, the input data should follow the following format requirements. There are five data entries per card preceeded by the location of the first item (Columns 1-9) on the card. This format facilitates reading a variable number of pieces of real data into a specified location in an array; as a result the order of these data cards to one another is immaterial and they may be in sequential or nonsequential order.

The number (index) in positions 1-9 of the first field on each card defines the location of the first piece of data on that card. If the index is 101, the first piece of data is stored in the 101st location; the remaining fields on each card contain data for the successive locations. If one or more of the data fields are left blank, no information is read into the locations corresponding to these fields; the information already in these locations (if any) remains unaltered. Hence, when running successive cases, certain items may be changed leaving others as they were previously.

Data read using the method described above must conform to the following specifications:

1. The index must be written to the extreme right of positions 1-9; and this index must not be zero or blank.

2. The floating point (real) data written in the five data fields may be written in two ways:

   (a) with a decimal point and no exponent
   (b) with the E12.8 type format where the decimal point is located eight places to the left of the beginning of the exponent field.

3. Data reading is concluded by placing a negative sign ahead of the index of the last card for the case. Data information may or may not be in the fields of this card.

Table X. Program Storage Location Map

Fortran Symbol		Formula for Computing Storage Location	Storage Location
*	LPRNT		
**	LIMX	NOTE: I = 20 (Total Possible Number of Species)	
*	IND		
*	N1		
*	N2	K = 50 (Total Possible Number of Reactions)	
*	N3		
*	N4		
*	N5		
*	R		1
**	XSTOP		2
*	W(23)	= I + 2	3 - [illegible]
*	G(10,20)	= 26 + 10(I-1)	26 - [illegible]
*	EL(10,20)	= 226 + 10(I-1)	226 - [illegible]
**	XN(20)	= 425 + I	426 - [illegible]
**	TABX(20)	= 445 + I	446 - [illegible]
**	TABY(20)	= 465 + I	466 - [illegible]
**	TABAP(20)	= 485 + I	486 - [illegible]
**	TE(20)	= 505 + I	506 - [illegible]
**	TV(20)	= 525 + I	526 - [illegible]
*	ELVBR(50,20)	= 545 + 50(I-1) + K	546 - [illegible]
*	GLVBR(50,20)	= 1545 + 50(I-1) + K	1546 - [illegible]
*	ALFA(50,20)	= 2545 + 50(I-1) + K	2546 - [illegible]
*	BETA(50,20)	= 3545 + 50(I-1) + K	3546 - [illegible]
*	FE(50,20)	= 4545 + 50(I-1) + K	4546 - [illegible]
*	BE(50,20)	= 5545 + 50(I-1) + K	5546 - [illegible]
*	FV(50,20)	= 6545 + 50(I-1) + K	6546 - [illegible]
*	BV(50,20)	= 7545 + 50(I-1) + K	7546 - [illegible]
*	CKAT(50)	= 8545 + K	8546 - [illegible]
*	XMU(50,20)	= 8595 + 50(I-1) + K	8596 - [illegible]
*	THETA(20)	= 9595 + I	9596 - [illegible]
*	YN(20)	= 9615 + I	9616 - [illegible]
*	FA(50)	= 9635 + K	9636 - 9685
*	FB(50)	= 9685 + K	9686 - [illegible]
*	FC(50)	= 9735 + K	9736 - 9785
*	BA(50)	= 9785 + K	9786 - [illegible]
*	BB(50)	= 9835 + K	9836 - [illegible]
*	BC(50)	= 9885 + K	9886 - 9935
*	HØVRW(20)	= 9935 + I	9936 - [illegible]
	TABS(20)	= 9955 + I	9956 - 9975
	ALPHA(50)	= 9975 + K	9976 - 10025
	BBETA(50)	= 10025 + K	10026 - 10075
	PHI(20)	= 10075 + K	10076 - 10095
	S		10096
**	[illegible]		[illegible]

**	TABX(20)	= 445 + I	446 - 465
**	TABY(20)	= 465 + I	466 - 485
**	TABAP(20)	= 485 + I	486 - 505
**	TE(20)	= 505 + I	506 - 525
**	TV(20)	= 525 + I	526 - 545
*	ELVBR(50,20)	= 545 + 50(I-1) + K	546 - 1545
*	GLVBR(50,20)	= 1545 + 50(I-1) + K	1546 - 2545
*	ALFA(50,20)	= 2545 + 50(I-1) + K	2546 - 3545
*	BETA(50,20)	= 3545 + 50(I-1) + K	3546 - 4545
*	FE(50,20)	= 4545 + 50(I-1) + K	4546 - 5545
*	BE(50,20)	= 5545 + 50(I-1) + K	5546 - 6545
*	FV(50,20)	= 6545 + 50(I-1) + K	6546 - 7545
*	BV(50,20)	= 7545 + 50(I-1) + K	7546 - 8545
*	CKAT(50)	= 8545 + K	8546 - 8595
*	XMU(50,20)	= 8595 + 50(I-1) + K	8596 - 9595
*	THETA(20)	= 9595 + I	9596 - 9615
*	YN(20)	= 9615 + I	9616 - 9635
*	FA(50)	= 9635 + K	9636 - 9685
*	FB(50)	= 9685 + K	9686 - 9735
*	FC(50)	= 9735 + K	9736 - 9785
*	BA(50)	= 9785 + K	9786 - 9835
*	BB(50)	= 9835 + K	9836 - 9885
*	BC(50)	= 9885 + K	9886 - 9935
*	HØVRW(20)	= 9935 + I	9936 - 9955
	TABS(20)	= 9955 + I	9956 - 9975
	ALPHA(50)	= 9975 + K	9976 - 10025
	BBETA(50)	= 10025 + K	10026 - 10075
	PHI(20)	= 10075 + K	10076 - 10095
	S		10096
**	STEP		10097
**	A		10098
**	COUNT		10099
**	TAUADJ		10100
**	UV		10101
**	P		10102
**	TT		10103
**	XMP		10104
**	X		10105
**	Y		10106
	RHØ		10107
	U		10108
	YY(62)		10109 - 10170
	F(62)		10171 - 10232
	SUMXN		10233

* These quantities are basic input data to the program. Generally speaking they will not be varied from case to case.

** These quantities are not only basic input data but are generally varied from case to case.

2

Since the input region is not cleared between cases, the input data from a previous case may be used in subsequent cases. Thus, when several cases are to be run consecutively and some of the input data are the same, these data items need not be re-entered.

5. PROGRAM OUTPUT

A complete set of sample printout is shown in Appendix III for the RAM-B3 streamline No. 5 case. The first batch of printing is the input data for the case. Again, all FORTRAN symbols are defined at the beginning of the report and for the most part the output is self-explanatory. The term "entries 1-5," etc., refers to the order in which the chemical reactions appear in the program. The main printout presents the local streamtube coordinates X and Y and the streamtube distance, S, as measured from the starting point. Next, the gross flow field properties (pressure, velocity, streamtube area, density, enthalpy, and translational temperature) are tabulated. The parameter EETT is included for reference only. It was originally the electronic energy based on translational temperature. It has recently been changed to the electronic energy based on the vibrational temperature of nitrogen. Following this output are the chemical composition, vibrational temperatures, electronic temperatures, the vibrational energies, and the electronic energies.

Between the printout for each integration interval one observes some miscellaneous information. This information is basically for diagnostic purposes and is purposely printed on separate pages so that it can readily be detached and eliminated from the main printout if so desired. The erms labeled HARMON, DES, and FORM represent the time constant term, the destruction term, and the formation term, respectively, in the vibrational rate equation. The other printout applies to the stability and accuracy tests in the integration subprogram. It indicates which integrated parameter is setting the integration step size and under what conditions it is doing so. The line of fixed point numbers represents the difference between the ordinates Y_2 and Y_3 (i.e., the denominator in the stability test) so that one can see which parameters would have denominators lying below the acceptable value of 75.0. This applies to the accuracy of the stability test.

The order in which the chemical species are considered both in the program computation and in the program output is always the same and as shown below:

N_2, O_2, NO, NO^+, N_2^+, O_2^+, O_2^-, N, O, N^+, O^+, O^-, e, Ar

SECTION IV

RESULTS FOR SAMPLE CASES

1. NORMAL SHOCK FLOW

Preliminary check runs were made for the case of pure oxygen dissociation behind a normal shock including finite vibrational excitation. The results are compared with those obtained by Treanor and Marrone, Reference (2), in Figure 8 . Two cases were run with the SD program. The first used the Millikan and White vibrational relaxation time constants, Reference (12), with electronic energy included in the species enthalpies. In the second run, Blackman's vibrational relaxation time constants, also used by Treanor and Marrone, were used and no electronic energies were considered. In all other respects, both the formulation and data corresponded to the Treanor and Marrone analysis. The two SD runs correctly show the expected difference using the shorter time constants which result from using the Millikan and White correlations. The second run was expected to duplicate the Reference (2) results, but as can readily be seen in Figure 8 , produced slightly different results. Although the temperatures in the "quasiequilibrium" zone downstream of $s = 0.1$ cm appear to be in fair agreement, a significant difference is apparent in the initial rate of vibrational temperature increase in the region $s < 0.05$ cm. To verify the SD results, exact hand calculations were made of the initial s -derivatives of all quantities being integrated, and the s -derivative of O_2 vibrational energy at $s = 0.0232$ cm. The initial derivative check showed exact agreement. At $s = 0.0232$ cm the following vibrational energy rate term was computed for the specie O_2.

$$\frac{d\epsilon_{v_i}}{ds} = \frac{1}{M_i w_i u}\left[\frac{\epsilon_{v_\infty} - \epsilon_{v_i}}{\tau_{v_i}}\right]$$

$= 4.42 \times 10^{11}$ ergs/gm-cm Hand Calculation

$= 4.42 \times 10^{11}$ ergs/gm-cm S&ID Program

$= 8.10 \times 10^{11}$ ergs/gm-cm Treanor and Marrone

This particular term is by far the largest one in determining the net effect, the chemical rate terms being small at this comparatively early point in the relaxation process behind the shock. Hand calculations were also made of the initial derivatives of all variables immediately behind the shock. Program results also checked the hand calculations. It is concluded that the SD program is correct.

The program was next used to compute the same case with preferential dissociation using $U = D/6k$, a value recommended in Reference 3 as being in agreement with experimental results. The effect of preferential

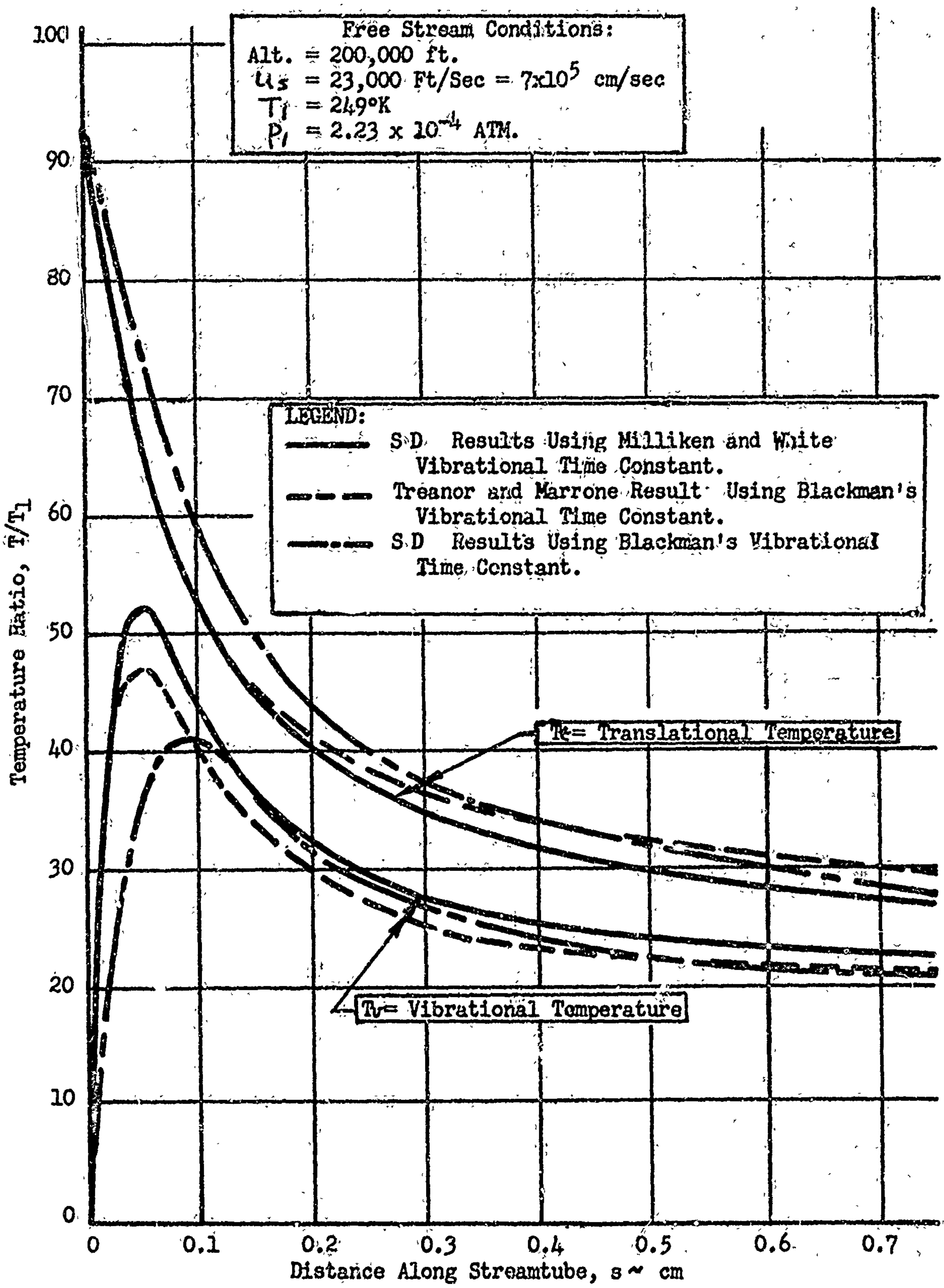


Figure 8. Normal Shock Relaxation in Pure O_2

dissociation is shown in Figure 9 , which compares the molecular oxygen concentration growth with that using $U \to \infty$ (non-preferential dissociation). The expected time lag effect on dissociation is seen to be present.

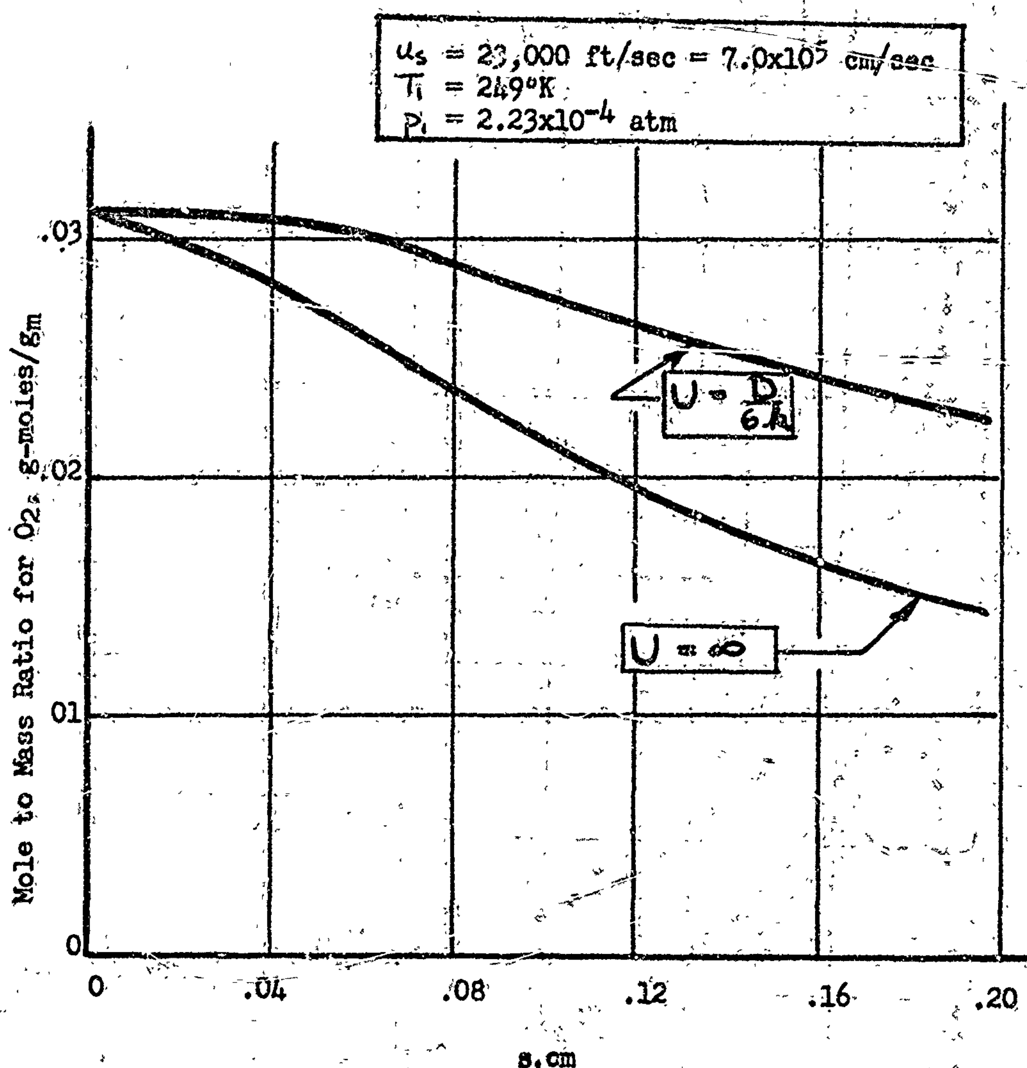


Figure 9. Preferential Dissociation Behind a Normal Shock in Pure Oxygen

Several normal shock cases for pure nitrogen were run with the Bortner chemical model and Milliken and White vibrational relaxation data. These runs are described more fully in Section II-6 . The runs included electronic excitation effects. It is of interest to show the data obtained on the final such run illustrating the relative contribution to the vibrational energy of N_2 from the relaxation term and the chemical formation and destruction terms. This comparison is presented in Figure 10.

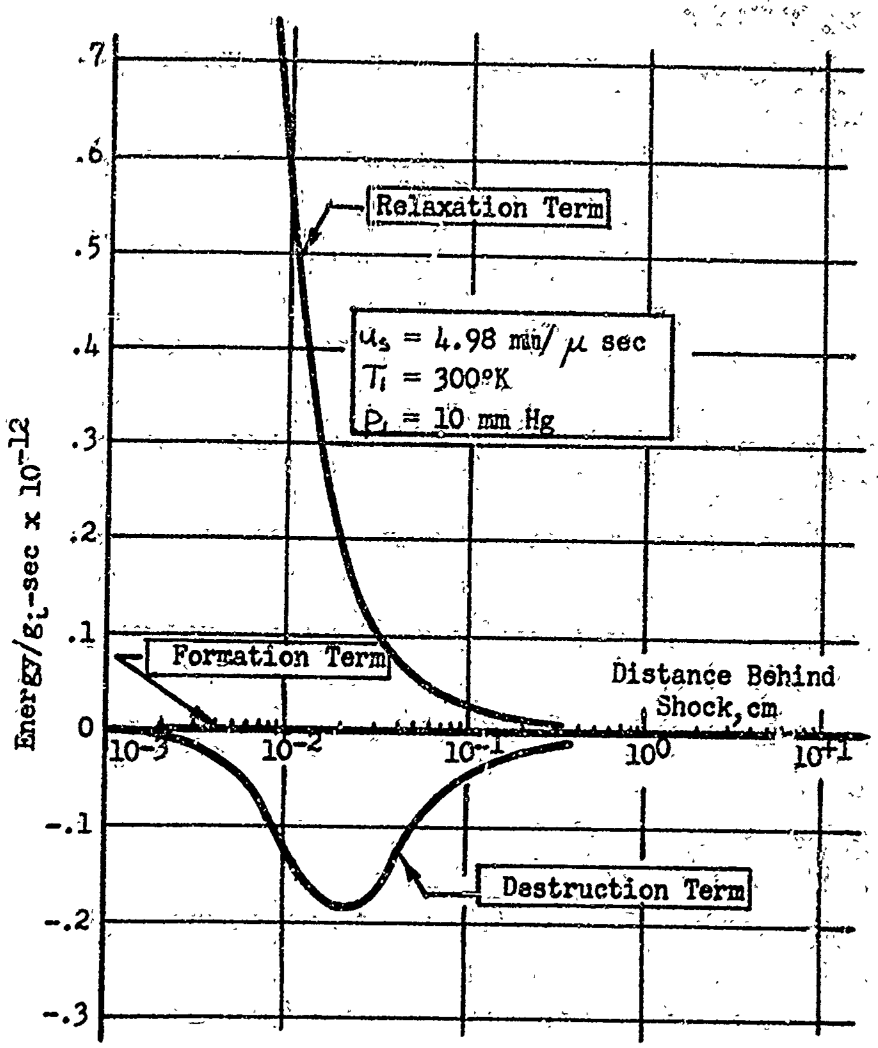


Figure 10. Comparison of Energy Terms in Vibrational Excitation of Shock-Heated Nitrogen

2 HYPERSONIC NOZZLE FLOW

A hypersonic nozzle flow case simulating conditions in the three megawatt facility at the Air Force Flight Dynamics Laboratory (AFFDL) was run with the SD program. The tunnel reservoir conditions for this case were specified as

$$P_T = 132.68 \text{ ATM}$$

$$H_T = 4284.76 \text{ BTU/LBm}$$

$$T_T = 5725.1°K$$

The starting point data along with a sample printout of a nozzle run made with the original program described in Reference 1 was furnished SD by AFFDL. The starting point was taken slightly downstream of the nozzle throat section and the flow was assumed to be in both thermal and chemical equilibrium. Vibrational and electronic temperatures were set equal to the translational temperature.

The selection of applicable chemical species for the air model is based on the species that would be present in mole fractions greater than 10^{-6} for either the nozzle case or the RAM-B3 case. Reactions 14, 15, and 20 were included for completeness in comparing RAM-B3 results even though the ionized species are not present with mole fractions greater than 10^{-6}. These are the dominant ionization reactions for these cases.

Input sheets for the nozzle case are presented in Appendix XI. Included with the initial starting point data is a description of the area-match parameter, TABAP, as a function of nozzle station, TABX. This latter data is based on the nozzle contour defined in Reference 22. Again, it should be emphasized that the input data presented in Appendix XI represent changes to the sample data for the RAM-B3, streamline No. 5 case.

Figure 11 shows the results of the SD run and gives the results of the AFFDL run for comparison. In the interest of simplicity, only curves for N and O are shown in Figure 11. The electronic temperature for N_2 appears to freeze immediately whereas a delay in the freezing is experienced for the vibrational temperature of N_2. The initial mole fractions of N and O were identical for the two runs and the decrease in the mole fraction of N, shown in Figure 11, takes place immediately. It can probably be traced to slight differences in the chemical rate data for the two programs.

Sample output sheets, representative of the results shown in Figure 11, are also presented in Appendix XI. The number of integration intervals (ICOUNT) and hence the run time proved quite large for the nozzle case. This is partially due to starting the problem under near-equilibrium conditions where the reaction equations are expected to be "stiff" and integration stability is indeed a major factor in setting step size. More important, however, was the fact that the program was still in checkout during the running of the nozzle case and five separate program runs were required to complete the nozzle case. Over one segment (the longest run) the integration procedure was not properly increasing step size. This deficiency was corrected on the

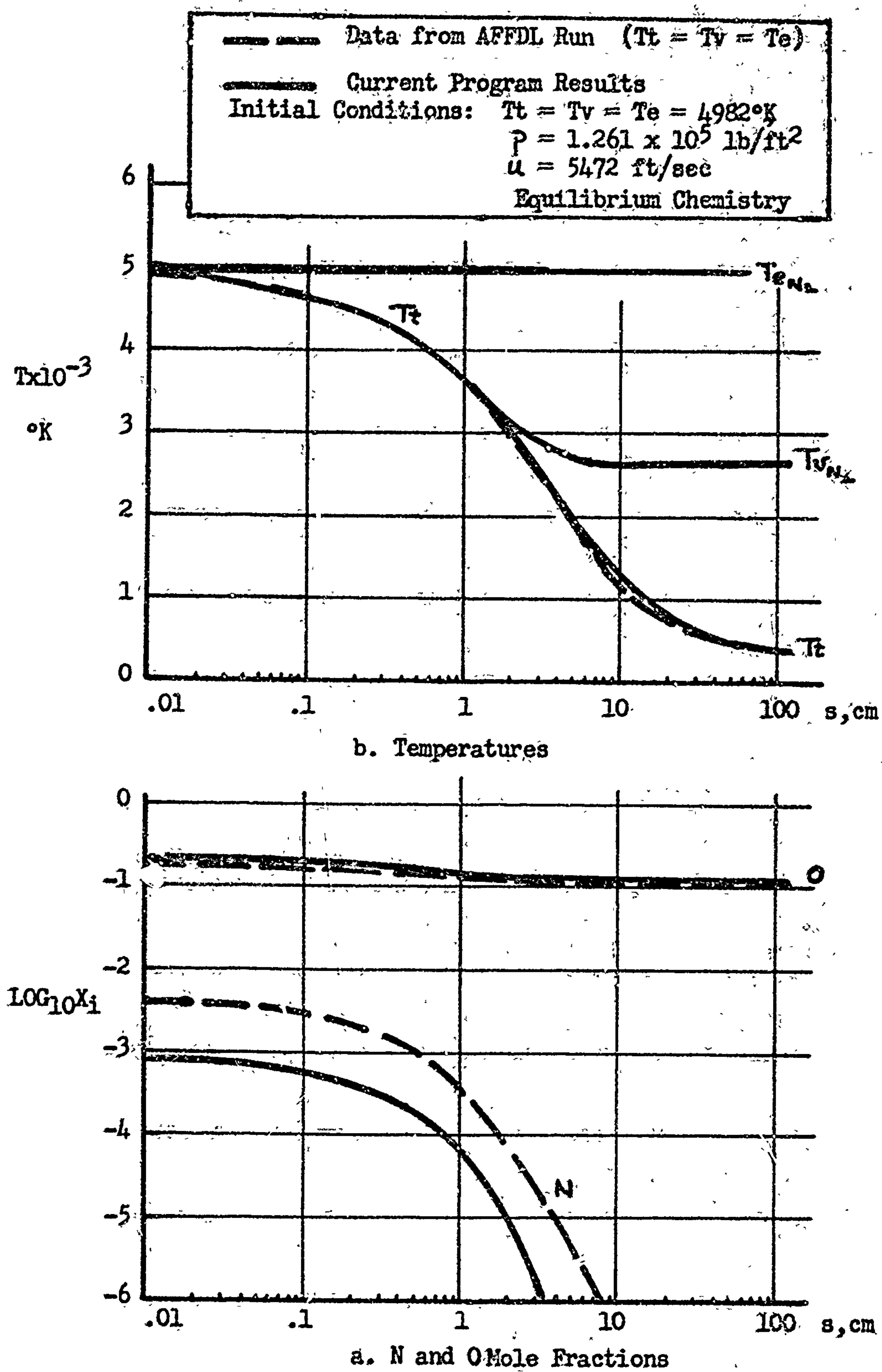


Figure 11. Expansion of Arc-Heated Air
In a Hypersonic Nozzle

subsequent runs. The actual run took thirty-five minutes to complete; but it is felt that with the final version of the computer program the run time would only require about fifteen to twenty minutes. It should be noted that while the program for this run was inefficient, the results are considered accurate.

3. RAM B3 FLOW FIELD ANALYSIS

The pressure matching portion of the new program was used to generate the external nonequilibrium flow field for the RAM B3 reentry configuration. The flow field generated was for Case No. 2 in the RAM B3 report, Reference 23 , where the flight conditions are as follows:

Velocity = 10,707 fps

Altitude = 135,539 ft

The RAM B3 configuration is a spherically-blunted, nine-degree, semi-apex angle cone which is shown in Figure 12 along with the eight streamlines for which data were generated during the course of this contract. The streamlines selected were direct counterparts of streamlines analyzed in Reference 23. Figure 12 presents, in addition to the selected streamline pattern, a series of body normals for which data is presented in Reference 23 . The dashed line shown in the figure represents the boundary layer build-up over the body surface.

Results were obtained for eight streamlines, and data plots are presented in Figures 13, 14 , and 15 for three typical streamlines (streamlines No. 5, 13, and 26). Beyond streamline No. 26 very little chemical, vibrational, and electronic energy excitation occurs. All three figures have the positions of normals designated so that with the aid of Figure 12 one can readily identify trends in the results with position along the streamline.

Streamline No. 5 was selected as the typical input-output case in Section III. It was also the only one of the eight to enter the boundary layer and all computation was stopped at that point. Changes in input data and sample output results for the other streamlines are furnished in Appendixes IV - X. The matching parameter history and the coordinates of the streamline are a part of the input data. The run time for these streamlines varied from one minute on streamline No. 38 to about five minutes on streamline No. 5.

Starting point conditions for RAM B3 streamlines were obtained from shock calculations assuming the translational and rotational energy modes are immediately equilibrated behind the shock. The chemical, vibrational, and electronic energy modes on the other hand are assumed to remain at free stream conditions through the shock itself and then proceed to relax as the flow moves downstream.

The initial concentrations of species N and O were set at 10^{-12} rather than 10^{-8}, as was the case in Reference 23, to give a more realistic representation of the initial transients behind the shock. The results for streamline No. 26 indicate even lower initial concentrations of these species are desirable but the program requires that all species included in the model be present in finite quantities for it to operate properly.

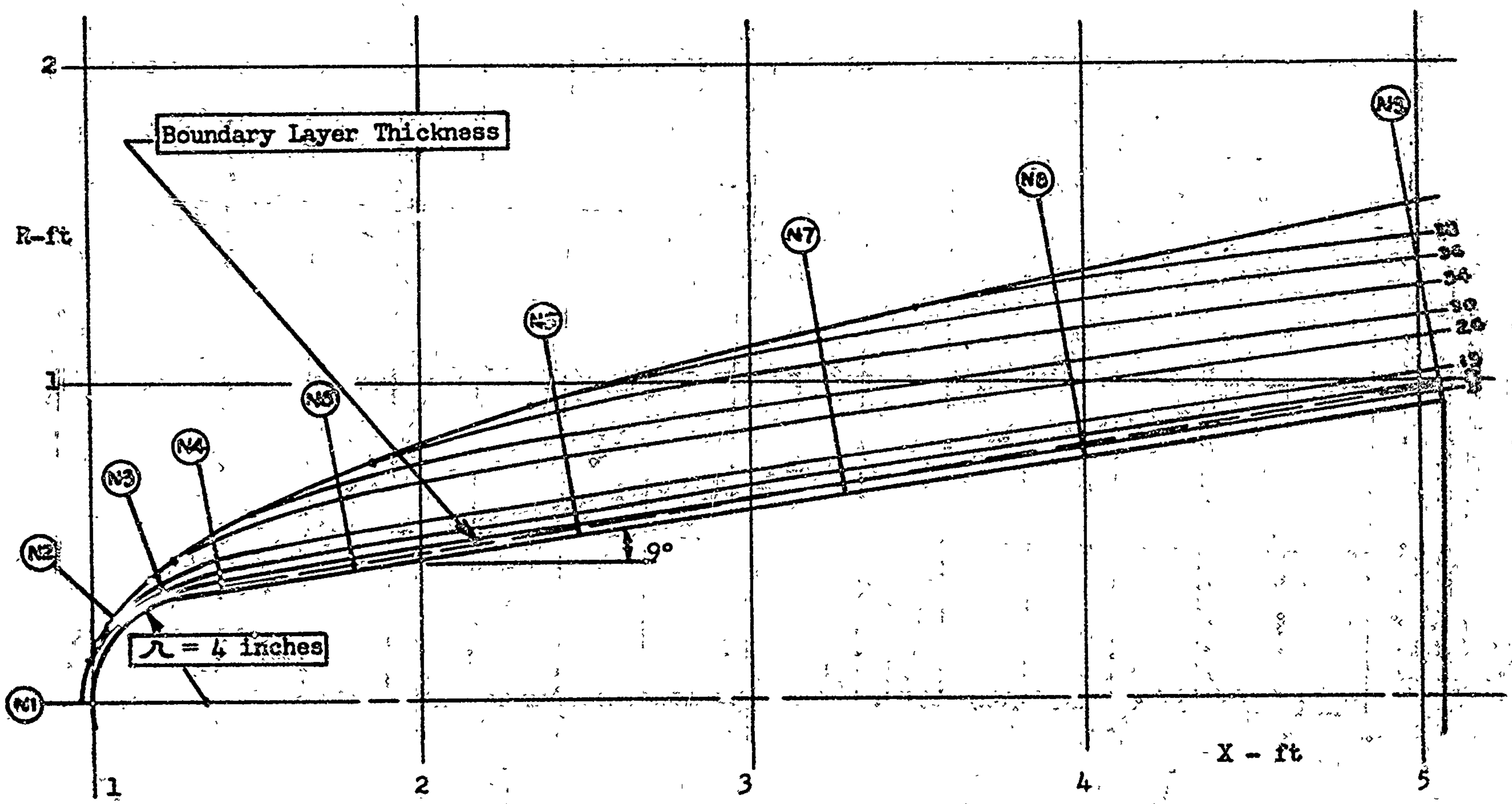
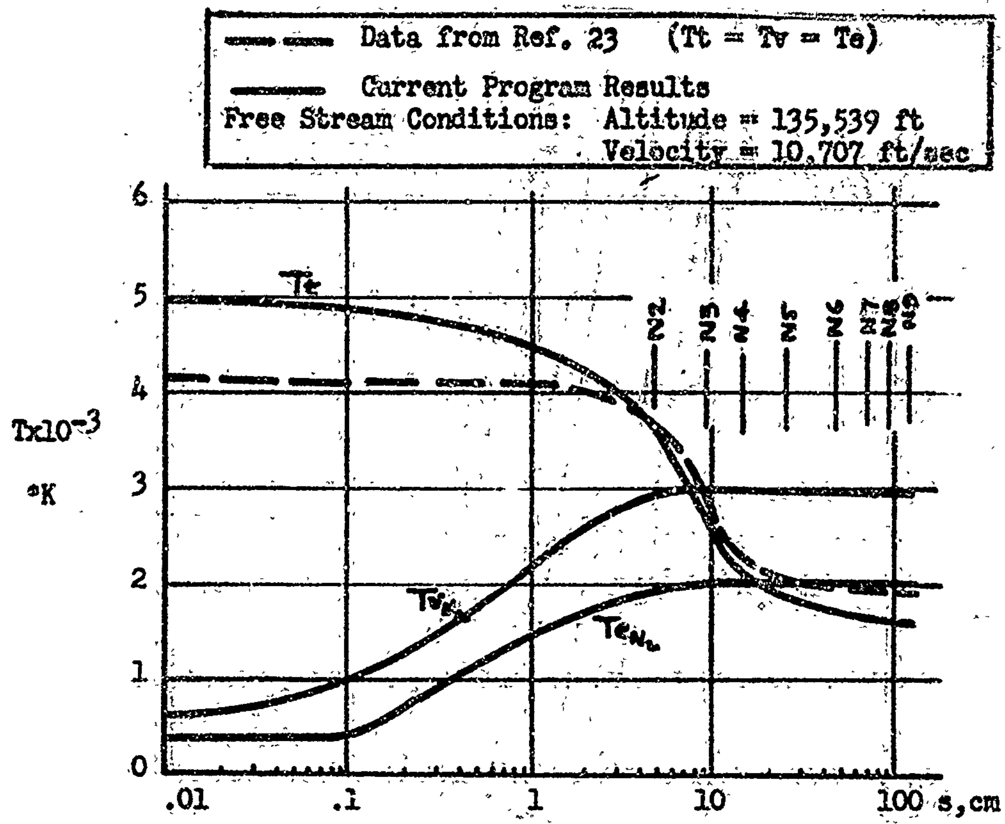
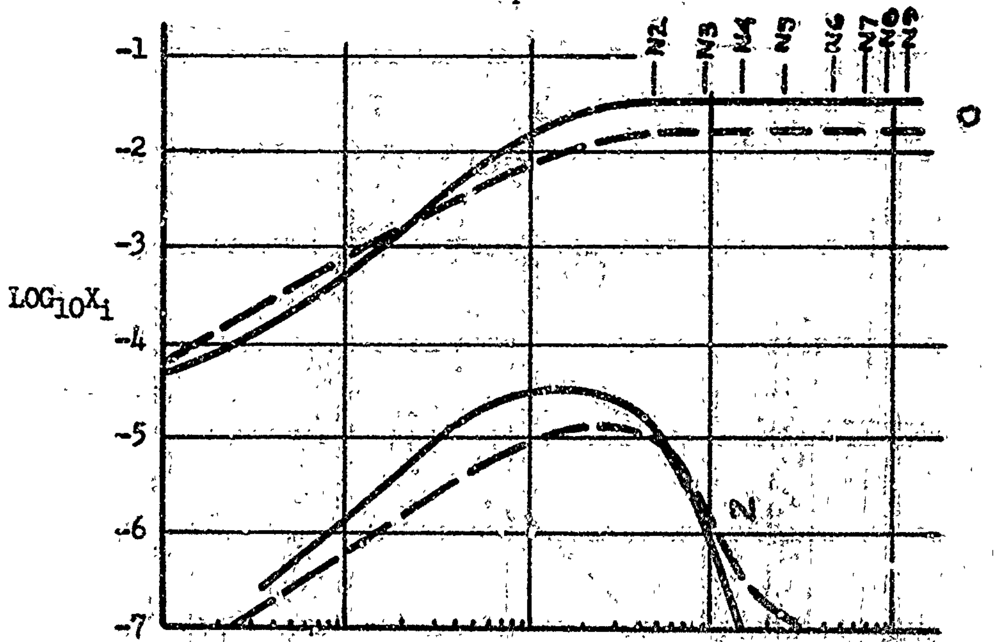


Figure 12. RAM-B3 Streamline Pattern

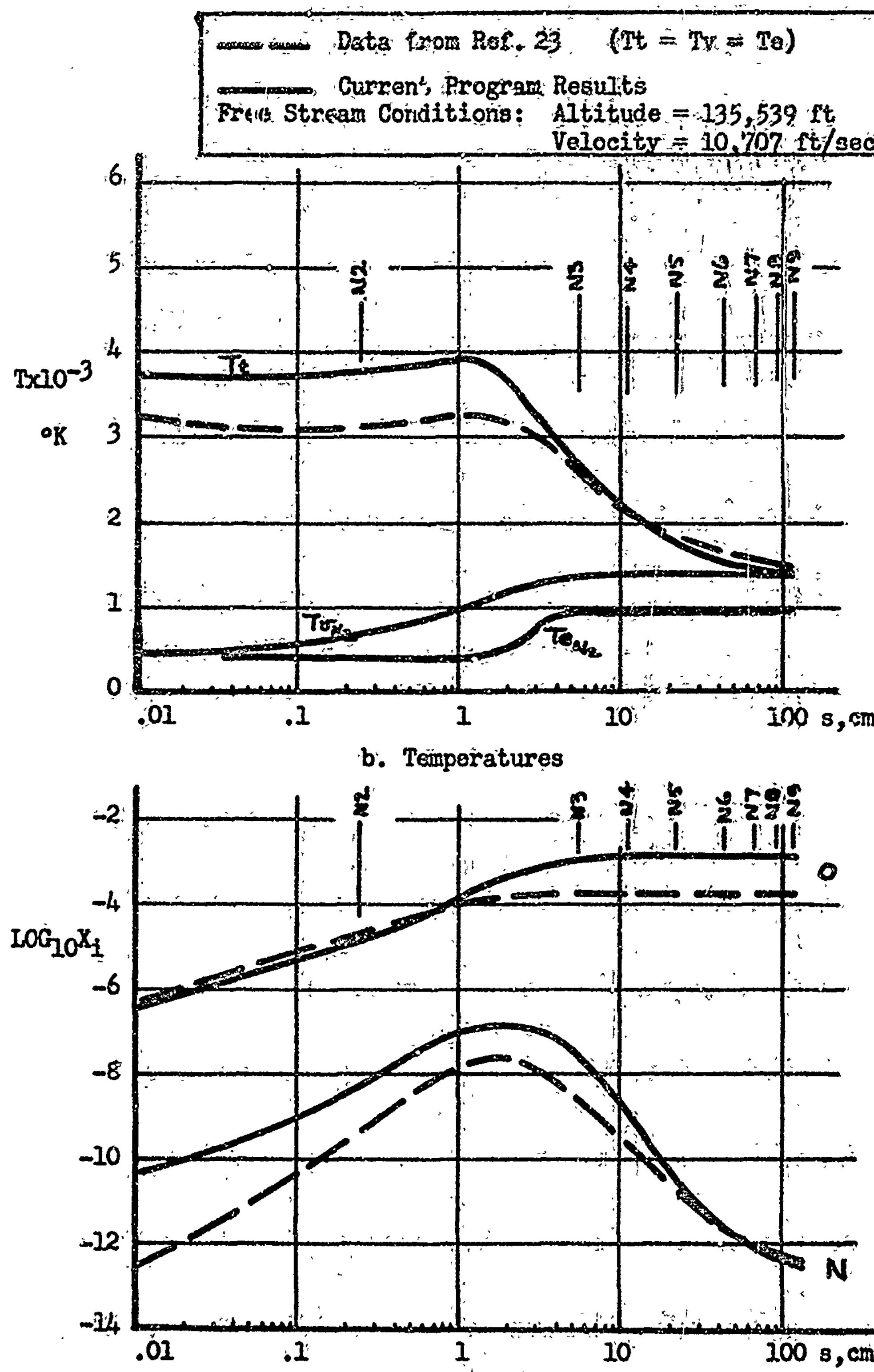


b. Temperatures



a. N and O Mole Fractions

Figure 13. RAM-B3 Nonequilibrium Flow Properties, Streamline No. 5



b. Temperatures

a. N and O Mole Fractions

Figure 14. RAM-B3 Nonequilibrium Flow Properties, Streamline No. 13

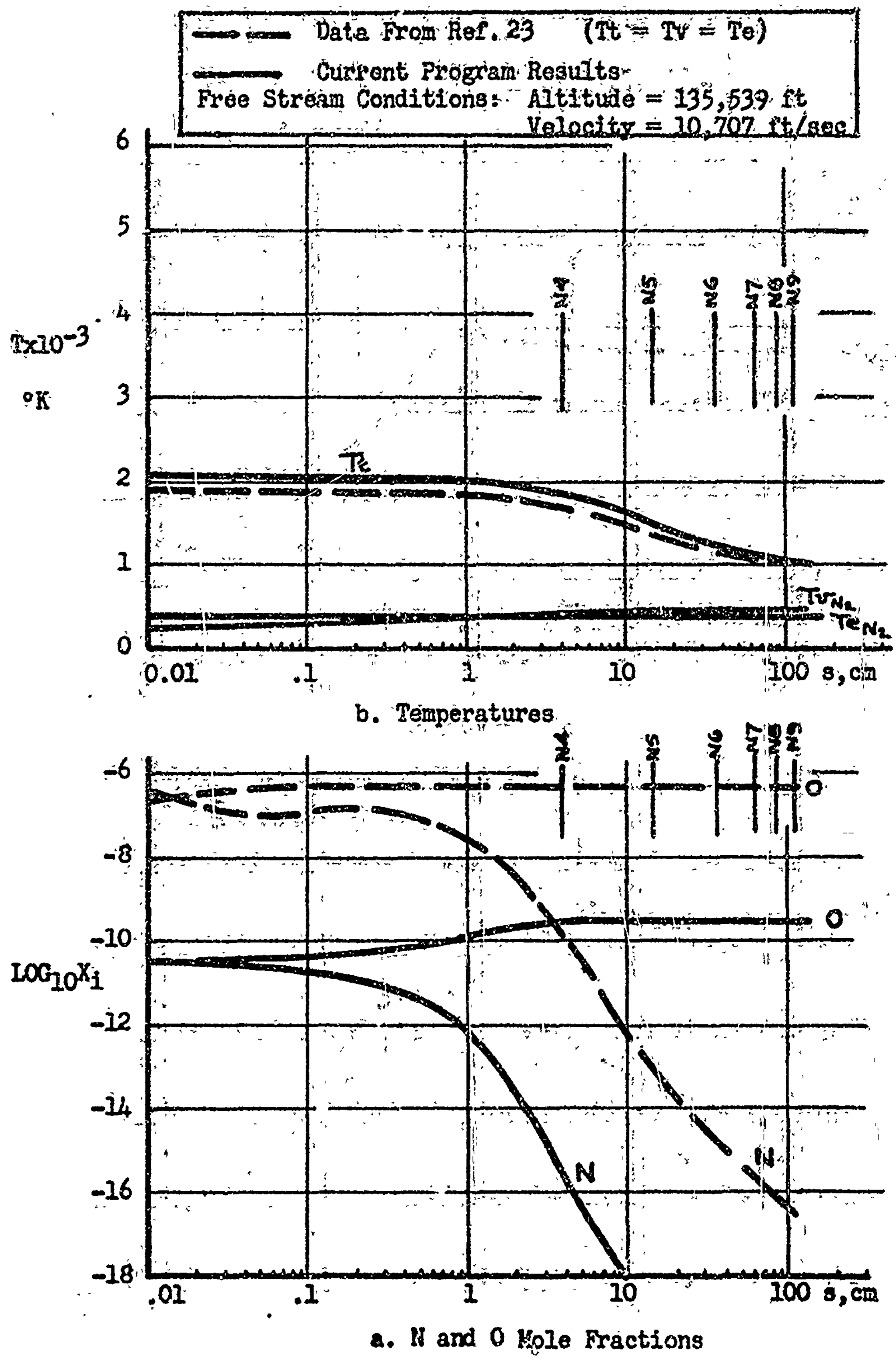


Figure 15. RAM-B3 Nonequilibrium Flow Properties, Streamline No. 26

APPENDIX I

VIBRATIONAL ENERGY BALANCE

The derivation of the vibrational energy equation (Equation (8) in the main text) is based on a simple energy balance. Consider dE_{v_i}/dt to be the time rate of change of vibrational energy per gram of mixture. This rate is related to two effects: (1) the vibrational energy transfer due to molecular translation effects (no chemical effects), and (2) the effect on vibrational energy resulting from chemical changes. This can be put into equation form as follows:

$$\frac{dE_{v_i}}{dt} = \left[\frac{\text{time rate of vibrational energy transfer due to translation}}{\text{g (mixture)}}\right]$$

$$-\left[\left(\frac{\text{vibrational energy lost}}{\text{mole}_i}\right)\left(\frac{\text{moles}_i\text{ dissociated}}{\text{sec-g (mixture)}}\right)\right] \tag{I-1}$$

$$+\left[\left(\frac{\text{vibrational energy gained}}{\text{mole}_i}\right)\left(\frac{\text{moles}_i\text{ recombined}}{\text{sec-g (mixture)}}\right)\right]$$

Substituting the physical terms into Equation (I-1) yields

$$\frac{dE_{v_i}}{dt} = \left(\frac{E_{v_{i,\infty}} - E_{v_i}}{\tau_{v_{i\,(MIX)}}}\right) - \frac{\sum_{k=1}^{N_2} \bar{E}_{v_{k,i}} \left(\frac{dn_i}{dt}\right)_{k_{DEST}}}{m_i} + \frac{\sum_{k=1}^{N_2} \bar{G}_{v_{k,i}} \left(\frac{dn_i}{dt}\right)_{k_{FORM}}}{m_i} \tag{I-2}$$

The quantities $E_{v_{i,\infty}}$, E_{v_i}, and $\bar{E}_{v_{k,i}}$ are evaluated from the energy expression for the cutoff harmonic oscillator model shown below using T_i, T_{v_i}, and T_{F_i}, respectively.

$$E_{v_i}(T) = m_i R \left[\frac{\Theta_i}{\exp\left(\frac{\Theta_i}{T}\right) - 1} - \frac{N_i \Theta_i}{\exp\left(\frac{N_i \Theta_i}{T}\right) - 1}\right] \tag{I-3}$$

The temperature, T_{F_i}, is defined as

$$\frac{1}{T_{F_i}} = \frac{1}{T_{v_i}} - \frac{1}{T_t} - \frac{1}{U} \tag{I-4}$$

The energy term $\bar{G}v_{k,i}$ is obtained from Equation (I-3) using $T = -U$

Since we are basically interested in the vibrational energy rate per gram of species i, $d\epsilon v_i/dt$, for use in Equation (18), we can transform (I-2) by means of the relationship

$$\epsilon v_i = \frac{Ev_i}{m_i w_i} \tag{I-5}$$

Differentiating Equation (I-5) yields

$$\frac{d\epsilon v_i}{dt} = \frac{-Ev_i}{w_i m_i^2}\frac{dm_i}{dt} + \frac{1}{m_i w_i}\frac{dEv_i}{dt} \tag{I-6}$$

Substituting (I-2) into (I-6) and changing from time to streamline distance as the independent variable produces the relationship

$$\frac{d\epsilon v_i}{dt} = \frac{\sum_{k=1}^{N_2} Ev_i\left(\frac{dm_i}{ds}\right)_{NET}}{w_i u_i^2} + \frac{1}{m_i w_i}\left[\frac{1}{u}\left(\frac{Ev_{i,\infty} - Ev_i}{\tau v_{i\,(MIX)}}\right) - \frac{\sum_{k=1}^{N_2} \bar{E}v_{k,i}\left(\frac{dm_i}{ds}\right)_{k\,DEST.}}{m_i} + \frac{\sum_{k=1}^{N_2} \bar{G}v_{k,i}\left(\frac{dm_i}{ds}\right)_{k\,FORM.}}{m_i}\right] \tag{I-7}$$

which is identical to Equation (8) in the main text.

APPENDIX II

VIBRATIONAL RELAXATION IN A MULTICOMPONENT MIXTURE

The vibrational relaxation for a diatomic species which has translational collisions with a series of catalytic species and is vibrationally excited by each encounter must account for each separate collision in its overall makeup. Consider a single molecule of species A and the possibility that it will encounter either other A molecules or molecules of species B or C. The vibrational energy exchanged in the collision process is obtained in the following manner:

$$\frac{d\epsilon_A}{dt} = \left.\frac{d\epsilon_A}{dt}\right|_{A-A} + \left.\frac{d\epsilon_A}{dt}\right|_{A-B} + \left.\frac{d\epsilon_A}{dt}\right|_{A-C} + \ldots \qquad \text{(II-1)}$$

Each individual vibrational energy rate term in Equation (II-1) is defined as

$$\left.\frac{d\epsilon_A}{dt}\right|_{A-J} = \frac{\epsilon_\infty - \epsilon_A}{\tau_{A-J}} \qquad J = A, B, C, \ldots \qquad \text{(II-2)}$$

It should be noted in this analysis that the first of the two reacting species (i.e., species "A") is considered present in high dilution in the second-named gas and for this reason each value of τ_{A-J} is based on the partial pressure of the second gas media. The energies in the equations presented above are defined in terms of energy per molecule of species A. Substituting Equation (II-2) into Equation (II-1) yields

$$\frac{d\epsilon_A}{dt} = \frac{\epsilon_\infty - \epsilon_A}{\tau_{A-A}} + \frac{\epsilon_\infty - \epsilon_A}{\tau_{A-B}} + \frac{\epsilon_\infty - \epsilon_A}{\tau_{A-C}} + \ldots$$

or (II-3)

$$\frac{d\epsilon_A}{dt} = (\epsilon_\infty - \epsilon_A)\sum \frac{1}{\tau_{A-J}} = \frac{\epsilon_\infty - \epsilon_A}{\tau_i}$$

$$J = A, B, C, \ldots$$

where τ_i represents the mixture of gases and is defined as

$$\frac{1}{\tau_i} = \frac{1}{\tau_{A-A}} + \frac{1}{\tau_{A-B}} + \frac{1}{\tau_{A-C}} + \cdots \qquad \text{(II-4)}$$

The expression for the individual values of τ are obtained from the relationship

$$\tau_{A-J} = \frac{1}{P_i} \exp\left[1.175\times10^{3}\,\mu_{A-J}^{1/2}\,\theta^{4/3}\left(T t^{-1/3} - 0.015\,\mu_{A-J}^{1/4}\right) - 18.42\right] \qquad \text{(II-5)}$$

which, when substituted in Equation (II-4), yields

$$\frac{1}{\tau_i} = \frac{p_A}{\exp[\;]\big|_{J=A}} + \frac{p_B}{\exp[\;]\big|_{J=B}} + \frac{p_C}{\exp[\;]\big|_{J=C}} + \cdots \qquad \text{(II-6)}$$

The relationship given in Equation (II-3) can be generalized to apply to the complete gas media by multiplying each term in the equation by the number of molecules of species A per gram of mixture producing

$$\frac{dE_A}{dt} = \left(E_\infty - E_A\right) \sum_{J=A,B,C,\ldots} \frac{1}{\tau_{A-J}} \qquad \text{(II-7)}$$

Each τ_{A-J} is still based on the partial pressure of the "J" constituent.

In any mixture of perfect gases, Dalton's Law states that

$$p_{TOT} = p_A + p_B + p_C + \cdots$$

or

$$\frac{W_{TOT}\,RT}{w_{TOT}\,V} = \frac{W_A\,RT}{w_A\,V} + \frac{W_B\,RT}{w_B\,V} + \frac{W_C\,RT}{w_C\,V} + \cdots$$

It is easily shown that

$$\frac{p_A}{p_{TOT}} = \frac{\frac{W_A}{w_A}}{\frac{W_{TOT}}{w_{TOT}}} = \frac{M_A}{M_{TOT}} = X_A \qquad \text{(II-8)}$$

where W denotes mass and X represents the mole fraction of the species in question. Redefining τ for each constituent in terms of the total pressure, P_{TOT}, yields

$$\tau_A = \frac{1}{P_{TOT}} \exp\left[1.175\times10^{3} \mu_{A-J}^{1/2} \theta_A^{4/3} \left(T^{-1/3} - 0.015 \mu_{A-J}^{1/4} \right) - 18.42 \right] \quad \text{(II-9)}$$

Combining Equation (II-6) and (II-9) one obtains

$$\frac{1}{\tau_i} = \frac{P_A}{P_{TOT}\tau_A} + \frac{P_B}{P_{TOT}\tau_B} + \frac{P_C}{P_{TOT}\tau_C} + \cdots \quad \text{(II-10)}$$

and applying the mole fraction criteria of Equation (II-8) one finally obtains

$$\frac{1}{\tau_i} = \frac{X_A}{\tau_A} + \frac{X_B}{\tau_B} + \frac{X_C}{\tau_C} + \cdots \quad \text{(II-11)}$$

where τ_A, τ_B, τ_C, etc., are all based on the pressure P_{TOT} of the mixture. This is the result derived in Reference 12 and shown in Equation (30).

APPENDIX III. Input-Output Data for RAM-B3, Streamline No. 5

FORTRAN FIXED IC JIGIT DECIMAL DATA

DECK NO._____ PROGRAMMER_____ DATE_____ PAGE 1 of _____ JOB NO._____

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION	DO NOT KEY PUNCH
1	1 17			
13	1 14			
25	37 13			
37	1 7			
49				
61				
1	1			
13	831400000E08		R	
25	97.7		XSTCP	
37	28.016		W_1	N_2
49	32.0			O_2
61	30.01		W_3	NO
1	6			
13	30.01		W_5	NO^+
25				
37			W_7	
49				
61	14.0		W_8	N
1	11			
13	16.0		W_9	O
25				
37			W_{11}	
49				
61	.5400000E-3		W_{13}	e

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Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 2 of ______ JOB NO. ______

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	16		
13	39.944		W_{14} Ar
25			
37			
49			
61			
1	26		
13	1.0		$G_1 - G_5$ for N_2
25	3.0		
37	6.0		
49	2.0		
61	6.0		
1	31		
13	1.0		$G_6 - G_{10}$ for N_2
25			
37			
49			
61			
1	36		
13	3.0		$G_1 - G_5$ for O_2
25	2.0		
37	1.0		
49	3.0		
61	1.0		

FORM 114-C-17 REV. 7-58- VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 3 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION 73–80	DESCRIPTION DO NOT KEY PUNCH
1	41		
13	3.0		$G_6 - G_{10}$ for O_2
25			
37			
49			
61			
1	46		
13	2.0		$G_1 - G_5$ for NO
25	2.0		
37	2.0		
49	4.0		
61	4.0		
1	51		
13	2.0		$G_6 - G_{10}$ for NO
25	2.0		
37			
49			
61			
1	56		
13	1.0		$G_1 - G_5$ for NO^+
25	6.0		
37	3.0		
49	6.0		
61	2.0		

FORM 114-C-17 REV. 7-58 VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 4 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	96		
13	4.0		$G_1 - G_5$ for N
25	10.0		
37	6.0		
49	30.0	73 80	
61	64.0		
1	101		
13	378.0		$G_6 - G_{10}$ for N
25			
37			
49		73 80	
61			
1	106		
13	5.0		$G_1 - G_5$ for O
25	4.0		
37	5.0		
49	1.0	73 80	
61	8.0		
1	111		
13	24.0		$G_6 - G_{10}$ for O
25	53.0		
37	149.0		
49		73 80	
61			

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 5 of ______ JOB NO. ______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	146		
13	2.0		$G_1 - G_5$ for e
25			
37			
49		73 80	
61			
1	156		
13	1.0		$G_1 - G_5$ for Ar
25	17.0		
37	36.0		
49	108.0	73 80	
61	348.0		
1	226		
13	0.0		$EL_1 - EL_5$ for N_2
25	71700.0		
37	85500.0		
49	99400.0	73 80	
61	126000.0		
1	231		
13	137000.0		$EL_6 - EL_{10}$ for N_2
25			
37			
49		73 80	
61			

FORM 114-C-17 REV. 7-58-VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 6 OF ______ JOB NO. ______

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	236		
13	0.0		$EL_1 - EL_5$ for O_2
25	11350.0		
37	18900.0		
49	51500.0		
61	52100.0		
1	241		
13	71000.0		$EL_6 - EL_{10}$ for O_2
25			
37			
49			
61			
1	246		
13	0.0		$EL_1 - EL_5$ for NO
25	174.0		
37	63600.0		
40	65400.0		
61	78300.0		
1	251		
13	76800.0		$EL_6 - EL_{10}$ for NO
23	87600.0		
37			
49			
61			

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 7 of ______ JOB NO. ______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	256		
13	0.0		EL1-EL5 for NO+
25	58000.0		
37	85100.0		
49	105000.0	73 80	
61	105800.0		
1	296		
13	0.0		EL1-EL5 for N
25	27700.0		
37	41500.0		
49	123400.0	73 80	
61	139000.0		
1	301		
13	156000.0		EL6-EL10 for N
25			
37			
49		73 80	
61			
1	306		
13	0.0		EL1-EL5 for O
25	253.0		
37	22850.0		
49	48500.0	73 80	
61	107900.0		

FORM 114-C-17 REV. 7-58 - VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 8 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	311		
13	126000.0		EL6 - EL10 for O
25	140000.0		
37	148000.0		
49		73 80	
61			
1	356		
13	0.0		EL1 - EL5 for Ar
25	136000.0		
37	153000.0		
49	165000.0	73 80	
61	174800.0		
1	426		
13	.268500E-01		XN_1
25	.721000E-02		
37	.100000E-11		XN_3
49	.100000E-15	73 80	
61			XN_5
1	431		
13			XN_6
25			
37	.100000E-11		XN_8
49	.100000E-11	73 80	
61			XN_{10}

FORM 1__-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE 9 of ______ JOB NO.______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	436	73 – 80	
13			XN_{11}
25			
37	.100000E-15		XN_{13}
49	.322000E-03		
61			XN_{15}
1	446	73 – 80	
13	30.2		$TABX_1$ - $TABX_5$
25	30.35		
37	30.6		
49	30.75		
61	33.75		
1	451	73 – 80	
13	35.6		$TABX_6$ - $TABX_{10}$
25	37.2		
37	38.6		
49	39.88		
61	41.6		
1	456	73 – 80	
13	50.5		$TABX_{11}$ - $TABX_{15}$
25	58.4		
37	81.5		
49	110.0		
61	139.3		

FORM 114-C-17-REV. 7-58-VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 10 of ______ JOB NO. ______

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	461		
13	153.0		$TABX_{16} - TABX_{20}$
25	159.7		
37			
49			
61			
1	466		
13	3.813		$TABY_1 - TABY_5$
25	3.942		
37	4.22		
49	4.5		
61	9.0		
1	471		
13	9.31		$TABY_6 - TABY_{10}$
25	10.12		
37	10.64		
49	11.0		
61	11.32		
1	476		
13	12.85		$TABY_{11} - TABY_{15}$
25	14.17		
37	17.90		
49	22.45		
61	27.0		

FORM 114-C-17 REV. 7-53-VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 11 of ______ JOB NO. ______

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	481		
13	29.05		$TABY_{16} - TABY_{20}$
25	29.88		
37			
49			
61			
1	486		
13	275000.0		$TABAP_1 - TABAP_5$
25	300000.0		
37	299500.0		
49	295000.0		
61	162100.0		
1	491		
13	100000.0		$TABAP_6 - TABAP_{10}$
25	59500.0		
37	43250.0		
49	31950.0		
61	26000.0		
1	496		
13	19370.0		$TABAP_{11} - TABAP_{15}$
25	16020.0		
37	11670.0		
49	9900.0		
61	9350.0		

FORM 114-C-17 REV. 7-58-VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 12 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	501		
13	9300.0		$TABAP_{16}$ - $TABAP_{20}$
25	9290.0		
37			
49			
61		73 80	
1	506		
13	400.0		TE_1 - TE_5
25	400.0		
37	400.0		
49	400.0		
61		73 80	
1	511		
13	0.0		TE_6 - TE_{10}
25	0.0		
37	400.0		
49	400.0		
61		73 80	
1	516		
13	0.0		TE_{11} - TE_{15}
25	0.0		
37	400.0		
49	400.0		
61		73 80	

FORM 14-C-17 REV. 7-58-VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 13 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION 73–80	DESCRIPTION DO NOT KEY PUNCH
1	526		
13	264.8		$TV_1 - TV_5$
25	264.8		
37	264.8		
49	264.8		
61			
1	546		$ELVBR_1 - ELVBR_5$ for N_2
13	0.0		
25	1.0		
37	1.0		
49	0.0		
61	0.0		
1	551		
13	2.0		$ELVBR_6 - ELVBR_{10}$ for N_2
25	2.0		
37			
49			
61			
1	596		
13	1.0		$ELVBR_1 - ELVBR_5$ for C_2
25			
37			
49			
61	2.0		

FORM 156-C-17 REV. 7-58- VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 14 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	661		
13			$ELVBR_6 - ELVBR_{10}$ for O_2
25	2.0		
37			
49		73 80	
61			
1	646		
13			$ELVBR_1 - ELVBR_5$ for NO
25			
37			
49	2.0	73 80	
61	2.0		
1	651		
13	2.0		$ELVBR_6 - ELVBR_{10}$ for NO
25	2.0		
37			
49		73 80	
61			
1	656		
13			$ELVBR_{11} - ELVBR_{15}$ for NO
25			
37			
49	2.0	73 80	
61	2.0		

FORM 114-C-17 REV. 7-58 - VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 15 of ______ JOB NO. ______

Streamline No. 5, continued

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	706		
13			ELVBR$_{11}$ - ELVBR$_{15}$ for NO+
25			
37			
49	2.0		
61	2.0		
1	711		
13			ELVBR$_{16}$ - ELVBR$_{20}$ for NO+
25			
37			
49			
61	2.0		
1	1546		
13			GLVBR$_{1}$ - GLVBR$_{5}$ for N$_2$
25	1.0		
37	1.0		
49			
61			
1	1551		
13	3.0		GLVBR$_{6}$ - GLVBR$_{10}$ for N$_2$
25	3.0		
37			
49			
61			

FORM 114-C-17 REV. 7-58-VELLUM

Streamline No. 5, continuod

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 16 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	1596		
13	1.0		$GLVBR_1 - GLVBR_5$ for O_2
25			
37			
49			
61	3.0		
1	1601		
13			$GLVBR_6 - GLVBR_{10}$ for O_2
25	3.0		
37			
49			
61			
1	1646		
13			$GLVBR_1 - GLVBR_5$ for NO
25			
37			
49	3.0		
61	3.0		
1	1651		
13	3.0		$GLVBR_6 - GLVBR_{10}$ for NO
25	3.0		
37			
49			
61			

FORM 11-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 17 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1656	73 … 80	
13			$GLVBR_{11} - GLVBR_{15}$ for ND
25			
37			
49	2.0		
61	2.0		
1	1706	73 … 80	
13			$GLVBR_{11} - GLVBR_{15}$ for NO+
25			
37			
49	2.0		
61	1.0		
1	1711	73 … 80	
13			$GLVBR_{16} - GLVBR_{20}$ for NO+
25			
37			
49			
61	3.0		
1	2546	73 … 80	
13			$ALFA_1 - ALFA_4$ for N_2
25	1.0		
37	1.0		
49			
61			

Streamline No. 5, continued

FORM 116-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 18 of ______ JOB NO. ______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	2551		
13	1.0		$ALFA_6 - ALFA_{10}$ for N_2
25	1.0		
37			
49		73 80	
61			
1	2596		
13	1.0		$ALFA_1 - ALFA_5$ for O_2
25			
37			
49		73 80	
61			
1	2601		
13			$ALFA_6 - ALFA_{10}$ for O_2
25	1.0		
37			
49		73 80	
61			
1	2646		
13			$ALFA_1 - ALFA_5$ for NO
25			
37			
49	1.0	73 80	
61	1.0		

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO._____ PROGRAMMER_____ DATE_____ PAGE 19 of_____ JOB NO._____

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	2656		
13			$ALFA_{11}$ – $ALFA_{15}$ for NC
25			
37			
49	1.0	73 80	
61	1.0		
1	2896		
13			$ALFA_1$ – $ALFA_5$ for N
25			
37	1.0		
49		73 80	
61			
1	2911		
13			$ALFA_{16}$ – $ALFA_{20}$ for N
25			
37			
49		73 80	
61	1.0		
1	2946		
13			$ALFA_1$ – $ALFA_5$ for O
25			
37			
49		73 80	
61	1.0		

FORM 114-C-17 REV. 7-58- VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 20 of ______ JOB NO. ______

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	2951		
13	1.0		$ALFA_6 - ALFA_{10}$ for 0
25			
37			
49			
61			
1	2961		
13			$ALFA_{16} - ALFA_{20}$ for 0
25			
37			
49			
61	1.0		
1	3156		
13			$ALFA_{11} - ALFA_{15}$ for e
25			
37			
49			
61	1.0		
1	3596		
13			$BETA_1 - BETA_5$ for 0_2
25			
37			
49			
61	1.0		

FORM 114-C-17 REV. 7-58- VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE 21 of ______ JOB NO.______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	3651		
13	1.0		BETA6 - BETA10 for NO
25	2.0		
37			
49		73 80	
61			
1	3706		
13			BETA11 - BETA15 for NO+
25			
37			
49	1.0	73 80	
61	1.0		
1	3711		
13			BETA16 - BETA20 for NO+
25			
37			
49		73 80	
61	1.0		
1	3896		
13			BETA1 - BETA5 for N
25	2.0		
37	3.0		
49	1.0	73 80	
61	1.0		

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FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 22 of ______ JOB NO. ______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	3701		
13	1.0		$BETA_6 - BETA_{10}$ for N
25			
37			
49			
61		73 80	
1	3946		
13	2.0		$BETA_1 - BETA_5$ for O
25			
37			
49	1.0		
61		73 80	
1	4156		
13			$BETA_{11} - BETA_{15}$ for Θ
25			
37			
49	1.0		
61	2.0	73 80	
1	4161		
13			$BETA_{16} - BETA_{20}$ for Θ
25			
37			
49			
61	1.0	73 80	

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FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE 25 of ____ JOB NO.______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	6546		
13			$FV_1 - FV_5$ for N_2
25	1.0		
37	1.0		
49		73 80	
61			
1	6596		
13	1.0		$FV_1 - FV_5$ FOR O_2
25			
37			
49		73 80	
61			
1	8546		
13	1.0		$CKAT_1 - CKAT_5$
25	1.0		
37			
49	1.0	73 80	
61			
1	8556		
13			$CKAT_4 - CKAT_5$
25			
37			
49	1.0	73 80	
61			

FORM 114-C-17 REV. 7-58- VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 24 of ______ JOB NO. ______

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	8596		
13	2.0		$XMU_1 - XMU_5$ FOR N_2
25	2.47		
37			
49	1.0		
61			
1	8606		
13			$XMU_{11} - XMU_{15}$ FOR N_2
25			
37			
49	216.0		
61			
1	8646		
13	9.0		$XMU_1 - XMU_5$ FOR O_2
25	1.0		
37			
49	1.0		
61			
1	8656		
13			$XMU_{11} - XMU_{15}$ FOR O_2
25			
37			
49	855.0		
61			

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 25 of ______ JOB NO. ______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	8.6.9.6		
13	1.0		
25	1.0		XMU_1 - XMU_5 FOR NO
37			
49	19.65		
61			
1	8706		
13			
25			XMU_{11} - XMU_{15} FOR NO
37			
49	1.0		
61			
1	8946		
13	1.0		
25			XMU_1 - XMU_5 FOR N
37			
49	19.65		
61			
1	8956		
13			
25			XMU_{11} - XMU_{15} FOR N
37			
49	5.9		
61			

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FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 26 of ______ JOB NO. ______

Streamline No. 5, continued

Field	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	8996		
13	25.0		$XMU_1 - XMU_5$ FOR 0
25	1.0		
37			
49	19.65		
61			
1	9006		
13			$XMU_{11} - XMU_{15}$ FOR 0
25			
37			
49	5.9		
61			
1	9246		
13	1.0		$XMU_1 - XMU_5$ FOR A_F
25	1.0		
37			
49	1.0		
61			
1	9256		
13			$XMU_{11} - XMU_{15}$ FOR A_F
25			
37			
49	5.9		
61			

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE 27 of______ JOB NO.______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION 73–80	DESCRIPTION DO NOT KEY PUNCH
1	9596		
13	3374.0		$\theta_1 - \theta_5$
25	2256.0		
37	2719.0		
49	3397.0		
61			
1	9616		
13	33.0		$YN_1 - YN_5$
25	26.0		
37	27.0		
49	36.0		
61			
1	9636		$FA_1 - FA_5$
13	3620000000E13		
25	1929000000E12		
37	4160000000E17		
49	3980000000E15		
61	3190000000E01		
1	9641		
13	6750000000E08		$FA_6 - FA_{10}$
25	8110000000E08		
37			
49			
61			

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 28 of ______ JOB NO. ______

		NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1		9646		
13				FA_{11} FA_{15}
25				
37				
49		20400000E10	73 80	
61		16880000E26		
1		9651		
13				FA_{16} - FA_{20}
25				
37				
49			73 80	
61		9040.0		
1		9686		
13	-	1.0		FB_1 - FB_5
25	-	0.5		
37	-	1.5		
49	+	1.5	73 80	
61		1.0		
1		9691		
13		0.0		FB_6 - FB_{10}
25	-	0.5		
37				
49			73 80	
61				

Streamline No. 5, continued

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 29 of ______ JOB NO. ______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	9696		
13			$FB_{11} - FB_{15}$
25			
37			
49	-1.0		
61	-3.0		
1	9701		
13			$FB_{16} - FB_{20}$
25			
37			
49			
61	0.5		
1	9736		
13	59.2		$EC_1 - EC_5$
25	113.1		
37	113.1		
49	75.6		
61	19.7		
1	9741		$EC_6 - EC_{10}$
13	37.5		
25	61.6		
37			
49			
61			

FORM 110-C-17 REV. 7-58 - VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO._____ PROGRAMMER_____ DATE_____ PAGE 30 of_____ JOB NO._____

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	9746		
13			$FC_{11} - FC_{15}$
25			
37			
49	107.9	73 80	
61	107.9		
1	9751		
13			$FC_{16} - FC_{20}$
25			
37			
49		73 80	
61	32.4		
1	9786		
13	36100000E10		$BA_1 - BA_5$
25	10870000E11		
37	23200000E16		
49	10150000E15	73 80	
61	96400000E06		
1	9791		
13	15030000E09		$BA_6 - BA_{10}$
25	60200000E05		
37			
49		73 80	
61			

FORM 114-C-17.REV. 7-58-VELLUM

Streamline No. 5, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 31 of ______ JOB NO. ______

		NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1		9796		$BA_{11} - BA_{15}$
13				
25				
37				
49		101700000E19	73 80	
61		835000000E34		
1		9801		$BA_{16} - BA_{20}$
13				
25				
37				
49			73 80	
61		18080000E14		
1		9836		$BB_1 - BB_5$
13	–	0.5		
25	–	0.5		
37	–	1.5		
49	–	1.5	73 80	
61		0.5		
1		9846		$BB_{11} - BB_{15}$
13				
25				
37				
49	–	2.5	73 80	
61	–	4.5		

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE 32 of ______ JOB NO. ______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	9.851		$BB_{16} - BB_{20}$
13			
25			
37			
49			
61	-1.0		
1	9.886		$BC_1 - BC_5$
13			
25			
37			
49			
61	3.6		
1	9.791		
13			$BC_6 - BC_{10}$
25	40.0		
37			
49			
61			
1	9.936		$HOVRW_1 - HOVRW_5$
13			
25			
37	3.05000000E12		
49	3.27000000E12		
61			

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER ______ DATE______ PAGE 33 of ______ JOB NO. ______

Streamline No. 5, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	996	73 … 80	
13			
25			HØVRW6 — HØVRW10
37	33950000E12		
49	15380000E12		
61			
1	10097	73 … 80	
13	0.00001		STEP
25	1.103		A
37	1.0		COUNT
49	1.0		TAUADT
61	0.0		UV
1	-10102	73 … 80	
13	22850000E06		P
25	54700000E0[illegible]		TT
37	1.0		XME
49	30.2		X
61	3.813		Y
1		73 … 80	
13			
25			
37			
49			
61			

FORM 114-C-17 REV. T-H-VELLUM

Streamline No. 5, continued

XN

0.26850000E-01	0.72100000E-02	0.10000000F-11	0.10000000F-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10000000F-11	0.10000000E-11	0.00000000E-38	0.00000000F-38	0.00000000E-38
0.10000000E-15	0.32200000F-03				

TABX

0.30200000E 02	0.30350000F 02	0.30600000F 02	0.30750000E 02	0.33750000F 02	0.35600000E 02
0.37200000F 02	0.38600000F 02	0.39880000E 02	0.41600000F 02	0.50500000F 02	0.58400000E 02
0.81500000E 02	0.11000000E 03	0.13930000F 03	0.15300000E 03	0.15970000E 03	

TABY

0.38130000E 01	0.39420000F 01	0.42200000E 01	0.45000000E 01	0.80000000E 01	0.93099999E 01
0.10120000E 02	0.10640000F 02	0.11000000E 02	0.11320000F 02	0.12850000E 02	0.14170000E 02
0.17900000E 02	0.22450000E 02	0.27000000F 02	0.29050000E 02	0.29880000E 02	

TABAP

0.27500000F 06	0.30000000E 06	0.29950000E 06	0.29500000F 06	0.16210000E 06	0.10000000E 06
0.59500000F 05	0.43250000E 05	0.31950000F 05	0.26000000E 05	0.19370000E 05	0.16020000E 05
0.11670000E 05	0.99000000 04	0.93500000E 04	0.93000000E 04	0.92900000E 04	

ELVBR FOR N2

ENTRIES 1- 5	0.00000000F-38	0.10000000E 01	0.10000000E 01	0.00000000F-38	0.00000000E-38
ENTRIES 6- 10	0.20000000E 01	0.20000000F 01	0.00000000E-38	0.00000000E-38	0.00000000E-38

```
ELVAR FOR   O2
ENTRIES  1- 5   0.10000000E 01   0.00000000E-38   0.00000000E-38   0.00000000E-38   0.20000000E 01
ENTRIES  6- 10  0.00000000E-38   0.20000000E 01   0.00000000E-38   0.00000000E-38   0.00000000E-38

ELVAR FOR   NO
ENTRIES  1- 5   0.00000000E-38   0.00000000E-38   0.00000000E-38   0.20000000E 01   0.20000000E 01
ENTRIES  6- 10  0.20000000E 01   0.20000000E 01   0.00000000E-38   0.00000000E-38   0.00000000E-38
ENTRIES 11- 15  0.00000000E-38   0.00000000E-38   0.00000000E-38   0.20000000E 01   0.20000000E 01

ELVAR FOR   NO+
ENTRIES 11- 15  0.00000000E-38   0.00000000E-38   0.00000000E-38   0.20000000E 01   0.20000000E 01
ENTRIES 16- 20  0.00000000E-38   0.00000000E-38   0.00000000E-38   0.00000000E-38   0.20000000E 01

ELVAR FOR   N

ELVAR FOR   O

ELVAR FOR   E

ELVAR FOR   AR

ELVAR FOR   N2
ENTRIES  1- 5   0.00000000E-38   0.10000000E 01   0.10000000E 01   0.00000000E-38   0.00000000E-38
ENTRIES  6- 10  0.30000000E 01   0.30000000E 01   0.00000000E-38   0.00000000E-38   0.00000000E-38

ELVAR FOR   O2
```

Streamline No. 5, continued

```
ENTRIES  1- 5   0.10000000E 01   0.00000000E-38   0.00000000E-38   0.00000000E-38   0.30000000E 01
ENTRIES  6- 10  0.00000000E-38   0.30000000E 01   0.00000000E-38   0.00000000E-38   0.00000000E-38

                          GLVBR FOR    NO
ENTRIES  1- 5   0.00000000E-38   0.00000000E-38   0.00000000E-38   0.30000000E 01   0.30000000E 01
ENTRIES  6- 10  0.30000000E 01   0.30000000E 01   0.00000000E-38   0.00000000E-38   0.00000000E-38
ENTRIES 11- 15  0.00000000E-38   0.00000000E-38   0.00000000E-38   0.20000000E 01   0.20000000E 01

                          GLVBR FOR    NO+
ENTRIES 11- 15  0.00000000E-38   0.00000000E-38   0.00000000E-38   0.20000000E 01   0.20000000E 01
ENTRIES 16- 20  0.00000000E-38   0.00000000E-38   0.00000000E-38   0.00000000E-38   0.30000000E 01

                          GLVBR FOR    N

                          GLVBR FOR    O

                          GLVBR FOR    F

                          GLVBR FOR    AR

STEP            UV               XMF              R                XSTOP            PRESSURE
0.10000000E-04  0.00000000E-38   0.10000000E 01   0.83140000E 08   0.97700000E 02   MATCH

                          SPECIE IS    N2      MOL. WT. IS  28.01600
                                               G
0.10000000E 01  0.30000000E 01   0.60000000E 01   0.20000000E 01   0.60000000E 01   0.10000000E 01
```

Streamline No. 5, continued

```
0.00000000F-38   0.00000000E-38   0.00000000F-38   0.00000000F-38

                                  FL

0.00000000E-38   0.71700000F 05   0.85500000E 05   0.59400000E 05   0.12600000E 06   0.13700000E 06
0.00000000F-38   0.00000000F-38   0.00000000E-38   0.C0000000E-38

                   SPECIF IS    O2     MOL. WT. IS  32.00000

                                  G

0.30000000F 01   0.20000000F 01   0.10000000F 01   0.30000000E 01   0.10000000E 01   0.30000000E 01
0.00000000F-38   0.00000000F-38   0.00000000F-38   0.00000000E-38

                                  FL

0.00000000E-38   0.11350000E 05   0.18900000F 05   0.51500000F 05   0.52100000F 05   0.71000000E 05
0.00000000F-38   0.00000000E-38   0.00000000E-38   0.00000000E-38

                   SPECIF IS    NO     MOL. WT. IS  30.01000

                                  G

0.20000000E 01   0.20000000F 01   0.20000000F 01   0.40000000F 01   0.40000000F 01   0.20000000E 01
0.20000000F 01   0.00000000F-38   0.00000000E-38   0.00000000F-38

                                  FL

0.00000000F-38   0.17400000E 03   0.63600000F 05   0.65400000F 05   0.75300000F 05   0.76800000E 05
0.87600000F 05   0.00000000F-38   0.00000000E-38   0.00000000E-38

                   SPECIF IS    NO+    MOL. WT. IS  30.01000

                                  G

0.10000000F 01   0.60000000F 01   0.30000000E 01   0.60000000E 01   0.20000000E 01   0.00000000E-38
0.00000000F-38   0.00000000E-38   0.00000000F-38   0.00000000E-38
```

Streamline No. 5, continued

```
                                        EL
0.00000000E-38   0.58000000E 05   0.85100000E 05   0.10500000E 06   0.10580000E 06   0.00000000E-38
0.00000000E-38   0.00000000E-38   0.00000000E-38   0.00000000E-38

                   SPECIE IS    N        MOL. WT. IS  14.00000

                                        G
0.40000000E 01   0.10000000E 02   0.60000000E 01   0.30000000E 02   0.64000000E 02   0.37800000E 03
0.00000000E-38   0.00000000E-38   0.00000000E-38   0.00000000E-38

                                        EL
0.00000000E-38   0.27700000E 05   0.41500000E 05   0.12340000E 06   0.13900000E 06   0.15600000E 06
0.00000000E-38   0.00000000E-38   0.00000000E-38   0.00000000E-38

                   SPECIE IS    O        MOL. WT. IS  16.00000

                                        G
0.50000000E 01   0.40000000E 01   0.50000000E 01   0.10000000E 01   0.80000000E 01   0.24000000E 02
0.53000000E 02   0.14900000E 03   0.00000000E-38   0.00000000E-38

                                        EL
0.00000000E-38   0.25300000E 03   0.22850000E 05   0.48500000E 05   0.10780000E 06   0.12600000E 06
0.14000000E 06   0.14800000E 06   0.00000000E-38   0.00000000E-38

                   SPECIE IS    E        MOL. WT. IS   0.00054

                                        G
0.20000000E 01   0.00000000E-38   0.00000000E-38   0.00000000E-38   0.00000000E-38   0.00000000E-38
0.00000000E-38   0.00000000E-38   0.00000000E-38   0.00000000E-38

                                        EL
```

Streamline No. 5, continued

```
0.00000000F-38   0.00000000E-38   0.09000000F-38   0.00000000E-38   0.00000000E-38   0.00000000E-38
0.00000000F-38   0.00000000  38   0.00000000F-38   0.00000000E-38

                 SPECIE IS   AR      MOL. WT. IS  39.94000

                                  G
0.10000000F 01   0.1200 000F 02   0.36000000F 02   0.10800000E 03   0.34800000E 03   0.00000000E-38
0.00000000F-38   0.00000000F-38   0.00000000E-38   0.00000000F-38

                                  EL
0.00000000F-38   0.13600000E 06   0.15300000E 06   0.16500000F 06   0.17480000F 06   0.00000000E-38
0.00000000E-38   0.00000000F-38   0.00000000E-38   0.00000000E-38

                                  TE
0.40000000F 03

                                  TV
0.26480000F 03   0.26480000E 03   0.26480000E 03   0.26480000E 03   0.00000000E-38   0.00000000E-38
0.00000000F-38

                 ALFA FOR    N2
ENTRIES  1- 5   0.00000000E-38   0.10000000F 01   0.10000000E 01   0.00000000E-38   0.00000000E-38
ENTRIES  6- 10  0.10000000E 01   0.10000000F 01   0.00000000E-38   0.00000000E-38   0.00000000E-38

                 ALFA FOR    O2
ENTRIES  1- 5   0.10000000F 01   0.00000000F-38   0.00000000F-38   0.00000000E-38   0.00000000E-38
ENTRIES  6- 10  0.00000000F-38   0.10000000E 01   0.00000000E-38   0.00000000F-38   0.00000000E-38
```

Streamline No. 5, continued

Streamline No. 5, continued

ALFA FOR NO

ENTRIES 1- 5	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01	0.10000000E 01
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01	0.10000000E 01

ALFA FOR NO+

ALFA FOR N

ENTRIES 1- 5	0.00000000E-38	0.00000000E-38	0.10000000E 01	0.00000000E-38	0.00000000E-38
ENTRIES 16- 20	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01

ALFA FOR O

ENTRIES 1- 5	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01
ENTRIES 6- 10	0.10000000E 01	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
ENTRIES 16- 20	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01

ALFA FOR E

ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01

ALFA FOR AR

BETA FOR N2

BETA FOR C2

ENTRIES 1- 5	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01

BETA FOR NO

ENTRIES 6- 10	0.10000000E 01	0.20000000E 01	0.00000000E-38	0.00000000E-38	0.00000000E-38
		BETA FOR NO+			
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01	0.10000000E 01
ENTRIES 16- 20	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01
		BETA FOR N			
ENTRIES 1- 5	0.00000000E-38	0.20000000E 01	0.30000000E 01	0.10000000E 01	0.10000000E 01
ENTRIES 6- 10	0.10000000E 01	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
		BETA FOR O			
ENTRIES 1- 5	0.20000000E 01	0.00000000E-38	0.00000000E-38	0.10000000E 01	0.00000000E-38
		BETA FOR E			
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01	0.20000000E 01
ENTRIES 16- 20	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.13000000E 01
		BETA FOR AR			
		FE FOR N2			
		FE FOR O2			
		FE FOR NO			
		FE FOR NO+			

Streamline No. 5, continued

FF FOR N

FF FOR O

FF FOR E

FF FOR AR

BF FOR N2

BF FOR O2

BF FOR NO

BF FOR NO+

BF FOR N

BF FOR O

BF FOR E

BF FOR AR

FV FOR N2

ENTRIES 1- 5 0.00000000E-38 0.10000000E 01 0.10000000E 01 0.00000000E-38 0.00000000E-38

FV FOR O2

Streamline No. 5, continued

ENTRIES 1- 5 0.10000000E 01 0.00000000E-38 0.00000000E-38 0.00000000E-38 0.00000000E-38

FV FOR NO

FV FOR NO+

FV FOR N

FV FOR O

FV FOR E

FV FOR AR

RV FOR N2

RV FOR O2

RV FOR NO

RV FOR NO+

RV FOR N

RV FOR O

RV FOR E

RV FOR AR

Streamline No. 5, continued

CKAT

0.10000000E 01	0.10000000E 01	0.00000000E-38	0.10000000E 01	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10000000E 01	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

XMU FOR N2

ENTRIES 1- 5	0.20000000E 01	0.24700000E 01	0.00000000E-38	0.10000000E 01	0.00000000E-38
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.21600000E 03	0.00000000E-38

XMU FOR O2

ENTRIES 1- 5	0.90000000E 01	0.10000000E 01	0.00000000E-38	0.10000000E 01	0.00000000E-38
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.85500000E 03	0.00000000E-38

XMU FOR NO

ENTRIES 1- 5	0.10000000E 01	0.10000000E 01	0.00000000E-38	0.19650000E 02	0.00000000E-38
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.10000000E 01	0.00000000E-38

XMU FOR NO+

Streamline No. 5, continued

XMU FOR N

ENTRIES 1- 5	0.10000000E 01	0.00000000E-38	0.00000000E-38	0.19650000E 02	0.00000000E-38
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.59000000E 01	0.00000000E-38

XMU FOR O

ENTRIES 1- 5	0.25000000E 02	0.10000000E 01	0.00000000E-38	0.19650000E 02	0.00000000E-38
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.59000000E 01	0.00000000E-38

XMU FOR E

XMU FOR AR

ENTRIES 1- 5	0.10000000E 01	0.10000000E 01	0.00000000E-38	0.10000000E 01	0.00000000E-38
ENTRIES 11- 15	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.59000000E 01	0.00000000E-38

THETA

0.33740000E 04	0.22560000E 04	0.27190000E 04	0.33970000E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

YN

0.33000000E 02	0.26000000E 02	0.27000000E 02	0.36000000E 02	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

FA

Streamline No. 5, continued

Streamline No. 5, continued

0.36200000E 13	0.19290000E 12	0.41600000E 17	0.39800000E 15	0.31900000E 04	0.67500000E 08
0.84400000E 08	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.20400000E 10	0.16880000E 26	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.90400000E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

FR

-0.10000000E 01	-0.50000000E 00	-0.15000000E 01	-0.15000000E 01	0.10000000E 01	0.00000000E-38
-0.50000000E 00	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	-0.10000000E 01	-0.30000000E 01	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.50000000E 00	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

FC

0.59400000E 02	0.11310000E 03	0.11310000E 03	0.75600000E 02	0.19700000E 02	0.37500000E 02

0.61600000E 02	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10790000E 03	0.10790000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.32400000E 02	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

BA

0.30100000E 10	0.10880000E 11	0.23200000E 16	0.10150000E 15	0.96400000E 06	0.15030000E 09
0.60200000E 05	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10170000E 19	0.83500000E 34	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.18080000E 14	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

BB

-0.50000000E 00	-0.50000000E 00	-0.15000000E 01	-0.15000000E 01	0.50000000E 00	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

0.00000000E-38	-0.25000000E 01	-0.45000000E 01	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	-0.10000000E 01	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

BC

0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.36000000E 01	0.00000000E-38
0.40000000E 02	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

HOVRW

0.00000000E-38	0.00000000E-38	0.30500000E 11	0.32700000E 12	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.33950000E 12	0.15380000E 12	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38				

Streamline No. 5, continued

TAB S

```
0.00000000E-38   0.19784074E 00   0.57171774E 00   0.88936536E 00   0.54991375E 01   0.77659856E 01
0.95593342E 01   0.11052787E 02   0.12382443E 02   0.14131962E 02   0.23162516E 02   0.31172035E 02
0.54571242E 02   0.83432158E 02   0.11308334E 03   0.12693586E 03   0.13368708E 03
UNDRFLOW AT 17316 IN MQ
UNDRFLOW AT 17321 IN MQ
UNDRFLOW AT 17322 IN MQ
UNDRFLOW AT 17316 IN MQ
UNDRFLOW AT 17321 IN MQ
UNDRFLOW AT 17322 IN MQ
UNDRFLOW AT 17316 IN MQ
UNDRFLOW AT 17321 IN MQ
UNDRFLOW AT 17322 IN MQ
UNDRFLOW AT 17316 IN MQ
UNDRFLOW AT 17321 IN MQ
UNDRFLOW AT 17322 IN MQ
UNDRFLOW AT 17316 IN MQ
UNDRFLOW AT 17321 IN MQ
UNDRFLOW AT 17322 IN MQ
UNDRFLOW AT 17332 IN AC
UNDRFLOW AT 17316 IN MQ
```

Streamline No. 5, continued

STARTING CONDITIONS ICOUNT = 1

X / RHO	Y / HSUM	S / TT	P / EFTT	U	A
0.30200000E 02	0.38130000E 01	0.00000000E-38	0.27500000E 06	0.11063798E 06	0.46600000E 00
0.19395897E-04	0.49491404E 11	0.49600000E 04	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72100000E-02	0.10000000E-11	0.10000000E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10000000E-11	0.10000000E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10000000E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26480000E 03	0.26480000E 03	0.26480000E 03	0.26480000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

FV(1) - FV(18)

0.22042162E 05	0.26986061E 06	0.78495267E-05	0.75777157E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

FE(1) - EF(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

```
M,ILOSV,XLO
  1   7   0.18632964E-01

  HARMON, DES,FORM
 -0.26414313E 07  -0.75830199F-04  -0.37239640E 02

  HARMON, DES,FORM
 -0.10413654E 09  -0.39715645E-01   0.26142939E 08

  HARMON, DES,FORM
 -0.28209971E 08   0.00000000E-38  -0.13699168E 02

  HARMON, DES,FORM
 -0.20099151E 07   0.00000000E-38  -0.11295400E-03

M,ILOSV,XLO
  2  13   0.27416484E-01

  HARMON, DES,FORM
  0.27026803E 07  -0.77002177E-04  -0.38823792E 02

  HARMON, DES,FORM
  0.10467167E 09  -0.40622426E-01   0.26123514E 08

  HARMON, DES,FORM
  0.28669297E 08   0.00000000E-38  -0.14461052E 02

  HARMON, DES,FORM
  0.20565002E 07   0.00000000E-38  -0.12944580E-03
   0.    47.     1. 13468.*******    95. 13468.   183.  1312.  1523.   145.     0. 46931. 13356.

   IHISV, ILOSV, XHI, XLO, HIGH,                  H
  5   5   0.35811048E 01   0.51336926E-01   0.60000000E 01   0.54586361E 00

  HARMON, DES,FORM
 -0.29609556E 07  -0.81830027E-04  -0.38827109E 02

  HARMON, DES,FORM
 -0.10340926E 09  -0.36376270E-01   0.26417873E 08

  HARMON, DES,FORM
```

Streamline No. 5, continued

ICOUNT = 25

X / RHO	Y / HSUM	S / TT	P / FFTT	U	A
0.30269166E 02	0.38724828E 01	0.91225793E-01	0.28652768E 06	0.10423461E 06	0.47018052E 00
0.20404381E-04	0.50179492E 11	0.49112892E 04	0.81907090E-20		

XN(1) - XN(18)

0.26849860E-01	0.72014713E-02	0.22437026E-06	0.52478793E-14	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.46643565E-07	0.16831233E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.52478793E-14	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.98019527E 03	0.24223143E 04	0.49254664E 04	0.45095084E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.24894510E 03	0.87829324E 09	0.68841094E 05	0.13186401E-02	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EF(18)

0.24597171E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

ICOUNT = 36

X / RHO	Y / HSUM	S / TT	P / EFTT	U	A
0.30409866E 02	0.40085713E 01	0.28737129E 00	0.29988027E 06	0.96440395E 05	0.47729502E 00
0.21724717E-04	0.50961881E 11	0.48221869E 04	0.72280605E-10		

XN(1) - XN(18)

0.26848108E-01	0.71601801E-02	0.34856750E-05	0.38516428E-12	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.28787622E-06	0.96153334E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.38516428E-12	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.14269239E 04	0.40345195E 04	0.48555753E 04	0.48386415E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TF(1) - TF(18)

0.99370393E 03	0.99370393E 03	0.99370393E 03	0.99370393E 03	0.99370393E 03	0.99370393E 03
0.99370393E 03	0.99370393E 03	0.99370393E 03	0.99370393E 03	0.99370393E 03	0.99370393E 03
0.99370393E 03	0.99370393E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

FV(1) - FV(18)

0.78133370E 09	0.17924833E 10	0.10497326E 07	0.10686787E 00	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EF(1) - EF(18)

0.22138903E-19	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

ICOUNT = 44

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.30883406E 02	0.46556409E 01	0.10943566E 01	0.28909009E 06	0.10338870E 06	0.43018099E 00
0.22484111E-04	0.50265691E 11	0.44595631E 04	0.72157521E-02		

XN(1) - XN(18)

0.26815798E-01	0.68810450E-02	0.67040869E-04	0.32860152E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.11740951E-05	0.59103088E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.32860152E-10	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.22523925E 04	0.43333043E 04	0.45544309E 04	0.45683325E 04	0.00000000E-38	[illegible]E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	[illegible]
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000[illegible]

TF(1) - TF(18)

0.15056684E 04	0.15056684E 04	0.15056684E 04	0.15056684E 04	0.15056684E 04	0.15056684E 04
0.15056684E 04	0.15056684E 04	0.15056684E 04	0.15056684E 04	0.15056684E 04	0.15056684E 04
0.15056684E 04	0.15056684E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.21661827E 10	0.18894212E 10	0.18557320E 08	0.84102160E 01	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.99959993E-09	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

ICOUNT = 51

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.32271409E 02	0.62749776E 01	0.32271489E 01	0.22760156E 06	0.12447445E 06	0.40840699E 00
0.19671008E-04	0.47863252E 11	0.39865272E 04	0.64904207E 01		

XN(1) - XN(18)

0.26739974E-01	0.65734960E-02	0.21876105E-03	0.14391919E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.88191655E-06	0.10544082E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.14391919E-09	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.28631797E 04	0.39766640E 04	0.41601305E 04	0.42850923E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.18857587E 04	0.18857587E 04	0.18857587E 04	0.18857587E 04	0.18857587E 04	0.18857587E 04
0.18857587E 04	0.18857587E 04	0.18857587E 04	0.18857587E 04	0.18857587E 04	0.18857587E 04
0.18857587E 04	0.18857587E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.33349334E 10	0.16148190E 10	0.53611734E 08	0.33607103E 02	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18).

0.14710479E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

ICOUNT = 64

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.34937017E 02	0.88405367E 01	0.69536177E 01	0.12225471E 06	0.17495936E 06	0.43576830E 00
0.13116175E-04	0.40306258E 11	0.32071304E 04	0.19394877E 02		

XN(1) - XN(18)

0.26715811E-01	0.65013249E-02	0.26800851E-03	0.16811780E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.16265580E-06	0.11495014E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.16811781E-09	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.29936201E 04	0.34589366E 04	0.37693089E 04	0.41497617E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TF(1) - TF(18)

0.19981673E 04	0.19981673E 04	0.19981673E 04	0.19981673E 04	0.19981673E 04	0.19981673E 04
0.19981673E 04	0.19981673E 04	0.19981673E 04	0.19981673E 04	0.19981673E 04	0.19981673E 04
0.19981673E 04	0.19981673E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

FV(1) - FV(18)

0.35916047E 10	0.13257292E 10	0.57306654E 08	0.37465444E 02	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EF(1) - EF(18)

0.12488725E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

ICOUNT = 69

X RHO	Y HSUM	S TT	P EETT	U	A
0.57729372E 02	0.10316624E 02	0.10124043E 02	0.53355505E 05	0.21155648E 06	0.64786203E 00
0.729[illegible]062E-05	0.33233770E 11	0.25161150E 04	0.19369327E 02		

XN(1) - XN(18)

0.26715209E-01	0.64993030E-02	0.26938496E-03	0.16827193E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.1761[illegible]68E-07	0.11521684E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.16827194E-09	0.3220[illegible]00E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.29934589E 04	0.32032391E 04	0.36508692E 04	0.41318703E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000 -38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.20105166E 04	0.20105166E 04	0.20105166E 04	0.20105166E 04	0.20105166E 04	0.20105166E 04
0.20105166E 04	0.20105166E 04	0.20105166E 04	0.20105166E 04	0.20105166E 04	0.20105166E 04
0.20105166E 04	0.20105166E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.35912013E 10	0.11923206E 10	0.55063956E 08	0.37263066E 02	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.15569458E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

ICOUNT = 77

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.48672854E 02	0.12535895E 02	0.21308568E 02	0.20731121E 05	0.24031307E 06	0.1097132[illegible]E 01
0.37928301E-05	0.26736876E 11	0.18806173E 04	0.19002827E 02		

XN(1) - XN(18)

0.26715223E-01	0.64991895E-02	0.26937393E-03	0.16821678E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.69364447E-09	0.11524057E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.16821679E-09	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.29910840E 04	0.[illegible]0002788E 04	0.35947325E 04	0.41271836E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.20150182E 04	0.20150182E 04	0.20150182E 04	0.20150182E 04	0.20150182E 04	0.20150182E 04
0.20150182E 04	0.20150182E 04	0.20150182E 04	0.20150182E 04	0.20150182E 04	0.20150182E 04
0.20150182E 04	0.20150182E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.35864532E 10	0.10873460E 10	0.53861869E 08	0.37188882E 02	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EF(1) - EF(18)

0.16861307E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, continued

ICOUNT = 81

X RHO	Y HSUM	Z TT	P FETT	U	A
0.59483696F 02	0.14344986F 02	0.32269768F 02	0.15815927F 05	0.24202712F 06	0.14004628E 01
0.29502878F-05	0.26323690F 11	0.18444679E 04	0.18852722F 02		

XN(1) - XN(18)

0.26715226E-01	0.64991759F-02	0.26936602E-03	0.16817690E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.61307969E-09	0.11524406E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.16817691E-09	0.32200000F-03	0.00000000F-38	0.00000000F-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.29900992F 04	0.29078690F 04	0.35712116E 04	0.41256060F 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000F-38	0.00000000F-38	0.00000000F-38	0.00000000F-38	0.00000000E-38
0.00000000F-38	0.00000000F-38	0.00000000F-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TF(1) - TF(18)

0.20169019E 04	0.20169019E 04	0.20169019E 04	0.20169019F 04	0.20169019F 04	0.20169019E 04
0.20169019F 04	0.20169019F 04	0.20169019E 04	0.20169019E 04	0.20169019F 04	0.20169019E 04
0.20169019F 04	0.20169019F 04	0.00000000E-38	0.00000000F-38	0.00000000F-38	0.00000000E-38

FV(1) - FV(18)

0.35844843F 10	0.10397692E 10	0.53358104F 08	0.37159210E 02	0.00000000E-38	0.00000000E-38
0.00000000F-38	0.00000000F-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000F-38	0.00000000F-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.17431353F-03	0.00000000E-38	0.00000000F-38	0.00000000F-38	0.00000000E-38	0.00000000E-38
0.00000000F-38	0.00000000F-38	0.00000000E-38	0.00000000F-38	0.00000000F-38	0.00000000E-38
0.00000000E-38	0.00000000F-38	0.00000000E-38	0.00000000E-38	0.00000000F-38	0.00000000E-38

Streamline No. 5, continued

ICOUNT = 86

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.10144147E 03	0.71083639E 02	0.74765250E 02	0.10431529E 05	0.25020718E 06	0.18412811E 01
0.21706016E-05	0.24310600E 11	0.1[illegible]35167E 04	0.18600486E 02		
XN(1) - XN(18)					
0.26715230E-01	0.64991721E-02	0.26935702E-03	0.16805043E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.16907095E-09	0.11524569E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.16805044E-09	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
TV(1) - TV(18)					
0.29884279E 04	0.27322707E 04	0.35284095E 04	0.41231342E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
TE(1) - TE(18)					
0.20204490E 04	0.20204490E 04	0.20204490E 04	0.20204490E 04	0.20204490E 04	0.20204490E 04
0.20204490E 04	0.20204490E 04	0.20204490E 04	0.20204490E 04	0.20204490E 04	0.20204490E 04
0.20204490E 04	0.20204490E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
EV(1) - EV(18)					
0.35811431E 10	0.94979230E 09	0.52443319E 08	0.37098621E 02	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
EE(1) - EE(18)					
0.18554498E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 5, concluded

APPENDIX IV. Input-Output Data for RAM-B3, Streamline No. 9

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE____ of____ JOB NO.______

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	1 17		LPRNT ITMX
13	1 14		IND N1
25	37 13		N2 N3
37	1 7		N4 N5
49			
61			
1	446		
13	31.03		$TABX_1 - TABX_5$
25	31.35		
37	31.45		
49	33.0		
61	34.8		
1	451		
13	36.15		$TABX_6 - TABX_{10}$
25	38.13		
37	41.0		
49	42.0		
61	43.75		
1	456		
13	46.3		$TABX_{11} - TABX_{15}$
25	53.5		
37	61.6		
49	78.3		
61	104.0		

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FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

Streamline No. 9, continued

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	461		
13	137.8		TABY16,17
25	155.7		
37			
49			
61			
1	466		
13	5.84		TABY1 – TABY5
25	6.03		
37	6.32		
49	7.95		
61	9.37		
1	471		
13	10.23		TABY6 – TABY10
25	11.24		
37	12.2		
49	12.48		
61	12.82		
1	476		
13	13.3		TABY11 – TABY15
25	14.6		
37	16.0		
49	18.7		
61	22.6		

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FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ___ of ___ JOB NO. ______

Streamline No. 9, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	481		
13	27.65		TABY 16,17
25	30.15		
37			
49		73 80	
61			
1	486		
13	240800.0		$TABAP_1 - TABAP_5$
25	270500.0		
37	262000.0		
49	197000.0	73 80	
61	134800.0		
1	491		
13	95600.0		$TABAP_6 - TABAP_{10}$
25	61200.0		
37	35600.0		
49	29350.0	73 80	
61	24300.0		
1	496		
13	22100.0		$TABAP_{11} - TABAP_{15}$
25	17980.0		
37	15170.0		
49	12040.0	73 80	
61	10120.0		

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FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

Streamline No. 9, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	5.01		
13	9360.0		TABAP 16,19
25	9300.0		
37			
49		73 80	
61			
1	10097		
13	0.00001		STEP
25	0.342		A
37	1.0		COUNT
49	1.0	73 80	TAUADJ
61			UV
1	-10102		
13	240800.0		P
25	4380.0		TT
37	1.0		XME
49	31.03	73 80	X
61	5.8A		Y
1			
13			
25			
37			
49		73 80	
61			

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STARTING CONDITIONS

ICOUNT = 1

X / RHO	Y / HSUM	S / TT	P / EFTT	U	A
0.31030000E 02	0.58400000E 01	0.00000000E-38	0.24080000E 05	0.15203118E 06	0.34200000E 03
0.19232743E-04	0.43704137E 11	0.43800000E 04	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72100000E-02	0.10000000E-11	0.10000000E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10000000E-11	0.10000000E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10000000E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26480000E 03	0.26480000E 03	0.26480000E 03	0.26480000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.22042162E 05	0.26986061E 06	0.78495267E-05	0.75777157E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 9, continued

ICOUNT = 21

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.31141264E 02	0.59060630E 01	0.12939867E 00	0.25112670E 06	0.14582515E 05	0.34051507E 00
0.20001533E-04	0.44482198E 11	0.43920372E 04	0.24597283E-25		

XN(1) - XN(18)

0.26849983E-01	0.72082080E-02	0.22625075E-07	0.14307200E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.43450591E-08	0.35600110E-05	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.14307200E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.80086400E 03	0.17903299E 04	0.43892405E 04	0.18020756E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.11316573E 09	0.53527892E 09	0.59614353E 04	0.72328065E-05	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597283E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 9, continued

ICOUNT = 24

X / RHO	Y / HSUM	S / TT	P / FFTT	U	A
0.31335078E 02	0.60211404E 01	0.35480252E 00	0.26911511E 06	0.14212394E 06	0.32571078E 00
0.21536348E-04	0.45161481E 11	0.43705380E 04	0.16977767E-17		

XN(1) - XN(18)

0.26849880E-01	0.72027743E-02	0.21024609E-06	0.18956138E-14	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.20806519E-07	0.14239979E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.18956138E-14	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.10572942E 04	0.29733353E 04	0.43832990E 04	0.40535924E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000011E 03	0.40000011E 03	0.40000011E 03	0.40000011E 03	0.40000011E 03	0.40000011E 03
0.40000011E 03	0.40000011E 03	0.40000011E 03	0.40000011E 03	0.40000011E 03	0.40000011E 03
0.40000011E 03	0.40000011E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.32302019E 09	0.11896701E 10	0.55296722E 05	0.40961019E-03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EF(1) - EF(18)

0.24597189E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 9, continued

Streamline No. 9, continued

ICOUNT = 35

X RHO	Y HSUM	S TT	P FETT	U	A
0.31670881E 02	0.65522817E 01	0.99944919E 00	0.25273723E 06	0.14792135E 06	0.31893919E 00
0.21196359E-04	0.44370670E 11	0.41668737E 04	0.12368593E-09		

XN(1) - XN(18)

0.26848860E-01	0.71727705E-02	0.22250394E-05	0.71008237E-13	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.82746039E-07	0.72240553E-04	0.00000000E-39	0.00000000E-38	0.00000000E-38
0.71008237E-13	0.32200000E-03	0.00000000E-38	0.00000000E-39	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.14423424E 04	0.39382358E 04	0.42439388E 04	0.42239476E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39	0.00000000E-38	0.00000000E-39
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.98782677E 03	0.98782677E 03	0.98782677E 03	0.98782677E 03	0.98782677E 03	0.98782677E 03
0.98782677E 03	0.98782677E 03	0.98782677E 03	0.98782677E 03	0.98782677E 03	0.98782677E 03
0.98782677E 03	0.98782677E 03	0.00000000E-38	0.00000000E-39	0.00000000E-38	0.00000000E-39

EV(1) - EV(18)

0.80349058E 09	0.17397305E 10	0.56026375E 06	0.16239060E-01	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39	0.00000000E-38	0.00000000E-24
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39

EE(1) - EE(18)

0.14412212E-19	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39

ICOUNT = 42

X	Y	S	P	U	A
RHO	HSUM	TT	FFTT		
0.33347502E 02	0.82241405E 01	0.33708423E 01	0.18499187E 06	0.17070986E 06	0.33784743E 00
0.17389804E-04	0.40774189E 11	0.37103265E 04	0.20980601E-04		

XN(1) - XN(18)

0.26843238E-01	0.70999189E-02	0.13349341E-04	0.80784403E-12	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.98378347E-07	0.20683915E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.80784403E-12	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.19033331E 04	0.37892026E 04	0.39137647E 04	0.39587643E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.12610120E 04	0.12610120E 04	0.12610120E 04	0.12610120E 04	0.12610120E 04	0.12610120E 04
0.12610120E 04	0.12610120E 04	0.12610120E 04	0.12610120E 04	0.12610120E 04	0.12610120E 04
0.12610120E 04	0.12610120E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.15409289E 10	0.16365516E 10	0.30082047E 07	0.16792699E 00	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.97210462E-13	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 9, continued

Streamline No. 9, continued

ICOUNT = 48

X	Y	S	P	U	A
RHO	HSUM	TT	FETT		
0.36605709E 02	0.10462458E 02	0.73331376E 01	0.87682631E 05	0.20862564E 06	0.46674778E 00
0.10269518E-04	0.33497734E 11	0.29767852E 04	0.20662896E-03		

XN(1) - XN(18)

0.26841067E-01	0.70841469E-02	0.17796292E-04	0.99988495E-12	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.14625505E-07	0.23393559E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99988496E-12	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.20263230E 04	0.33742561E 04	0.36435927E 04	0.38567431E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.13401484E 04	0.13401484E 04	0.13401484E 04	0.13401484E 04	0.13401484E 04	0.13401484E 04
0.13401484E 04	0.13401484E 04	0.13401484E 04	0.13401484E 04	0.13401484E 04	0.13401484E 04
0.13401484E 04	0.13401484E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.17566705E 10	0.13964756E 10	0.36273912E 07	0.19998014E 00	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.27916598E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

ICOUNT = 52

X RHO	Y HSUM	S TT	P FETT	U	A
0.39658084E 02	0.11751136E 02	0.10655592E 02	0.47559700E 05	0.23121491E 06	0.64904887E 00
0.66635669E-05	0.28529926E 11	0.24888665E 04	0.23322556E-03		

XN(I) - XN(18)

0.26840995E-01	0.70835812E-02	0.17953757E-04	0.10009871E-11	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.21167734E-08	0.23490929E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10009871E-11	0.37200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.20332775E 04	0.31850807E 04	0.35698139E 04	0.38482591E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.13496961E 04	0.13496961E 04	0.13496961E 04	0.13496961E 04	0.13496961E 04	0.13496961E 04
0.13496961E 04	0.13496961E 04	0.13496961E 04	0.13496961E 04	0.13496961E 04	0.13496961E 04
0.13496961E 04	0.13496961E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.17690561E 10	0.12892480E 10	0.35544307E 07	0.19943842E 00	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.40759639E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 9, continued

ICOUNT = 60

X RHO	Y HSUM	S TT	P FFTT	U	A
0.50946919E 02	0.14139027E 02	0.22208612E 02	0.19440929E 05	0.25309556E 06	0.11494215E 01
0.34386696E-05	0.23254237E 11	0.19710752E 04	0.23572645E-03		

XN(1) - XN(18)

0.26840989E-01	0.70834679E-02	0.17964225E-04	0.10009966E-11	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.80940301E-00	0.23512488E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10009966E-11	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.20338924E 04	0.30020042E 04	0.35200457E 04	0.38445358E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.13548580E 04	0.13548580E 04	0.13548580E 04	0.13548580E 04	0.13548580E 04	0.13548580E 04
0.13548580E 04	0.13548580E 04	0.13548580E 04	0.13548580E 04	0.13548580E 04	0.13548580E 04
0.13548580E 04	0.13548580E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.17701522E 10	0.11860683E 10	0.34857115E 07	0.19914983E 00	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EF(1) - EF(18)

0.49903589E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 9, continued

ICOUNT = 62

X RHO	Y HSUM	S TT	P EETT	U	A
0.61772229E 02	0.16019761E 02	0.33146888E 02	0.15147091E 05	0.25783582E 04	0.13407936E 01
0.28511763E-05	0.22020492E 11	0.18521728E 04	0.23532979E-03		

XN(1) - XN(18)

0.26840989E-01	0.70834464E-02	0.17964594E-04	0.10029953E-11	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.33489071E-10	0.23516248E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10009953E-11	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.20337953E 04	0.29209212E 04	0.35004501E 04	0.38433594E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.13567800E 04	0.13567800E 04	0.13567800E 04	0.13567800E 04	0.13567800E 04	0.13567800E 04
0.13567800E 04	0.13567800E 04	0.13567800E 04	0.13567800E 04	0.13567800E 04	0.13567800E 04
0.13567800E 04	0.13567800E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.17699790E 10	0.11405576E 10	0.34579362E 07	0.19925782E 00	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.53788398E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 9, continued

ICOUNT = 69

X RHO	Y HSUM	S TT	P EFTT	U	A
0.15500000E 03	0.29154481E 07	0.14416274E 03	0.93478923E 04	0.26671923E 06	0.18826477E 01
0.19914830E-05	0.19690698E 11	0.16364889E 04	0.23227875E-03		

XN(1) - XN(18)

0.76840987E-01	0.70834154E-02	0.17964795E 04	0.10009854E-11	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.52690758E-11	0.23522882E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10009854E-11	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.70330431E 04	[illegible] 06	[illegible] 04	0.38398162E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.13635441E 04	0.13635441E 04	0.13635441E 04	0.13635441E 04	0.13635441E 04	0.13635441E 04
0.13635441E 04	0.13635441E 04	0.13635441E 04	0.13635441E 04	0.13635441E 04	0.13635441E 04
0.13635441E 04	0.13635441E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.17686377E 10	0.96727086E 09	0.33558886E 07	0.19877945E 00	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.69910350E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 9, concluded

APPENDIX V. Input-Output Data for RAM-B3, Streamline No. 13

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1 16	73 … 80	LPRNT LIMX
13	1 14		IND N1
25	37 13		N2 N3
37	1 7		N4 N5
49			
61			
1	446	73 … 80	
13	32.2		$TABX_1$ – $TABX_5$
25	32.4		
37	34.75		
49	36.35		
61	38.73		
1	451	73 … 80	
13	40.95		$TABX_6$ – $TABX_{10}$
25	42.1		
37	44.65		
49	47.0		
61	52.4		
1	456	73 … 80	
13	61.9		$TABX_{11}$ – $TABX_{15}$
25	70.0		
37	85.8		
49	108.1		
61	135.7		

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Streamline No. 13, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	461		
13	158.8		$TABX_{16}$
25			
37			
49			
61			
1	466		
13	7.88		$TABY_1 - TABY_5$
25	8.02		
37	10.02		
49	11.05		
61	12.3		
1	471		
13	13.18		$TABY_6 - TABY_{10}$
25	13.53		
37	14.26		
49	14.72		
61	15.78		
1	476		
13	17.45		$TABY_{11} - TABY_{15}$
25	18.81		
37	21.28		
49	24.6		
61	28.45		

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Streamline No. 13, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE____ of____ JOB NO.______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	481		
13	31.62		$TABY_{16}$
25			
37			
49			
61			
1	486		
13	202300.0		$TABAP_1 - TABAP_5$
25	226000.0		
37	143000.0		
49	101000.0		
61	65750.0		
1	491		
13	45100.0		$TABAP_6 - TABAP_{10}$
25	37000.0		
37	26910.0		
49	22050.0		
61	18700.0		
1	496		
13	15280.0		$TABAP_{11} - TABAP_{15}$
25	13340.0		
37	11300.0		
49	9980.0		
61	9400.0		

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Streamline No. 13, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	5.01	73–80	
13	92900.0		TABAP 16
25			
37			
49			
61			
1	10097	73–80	
13	0.000001		STEP
25	0.273		A
37	1.0		COUNT
49	1.0		TAUADJ
61			UV
1	-10102	73–80	
13	2023000.0		P
25	3720.0		TT
37	1.0		XNF
49	32.2		X
61	7.88		Y
1		73–80	
13			
25			
37			
49			
61			

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STARTING CONDITIONS ICOUNT = 1

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.32200000E 02	0.78800000E 01	0.00000000E-38	0.20230000E 06	0.19254203E 06	0.27300000E 00
0.19024436E-04	0.37118326E 11	0.37200000E 04	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72100000E-02	0.10000000E-11	0.10000000E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10000000E-11	0.10000000E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10000000E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26480000E 03	0.26480000E 03	0.26480000E 03	0.26480000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-39	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - FV(18)

0.22042162E 05	0.26986061E 06	0.78495267E-05	0.75777157E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-36	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, continued

ICOUNT = 18

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.32320596E 02	0.79764766E 01	0.15443812E 00	0.21659060E 06	0.18859215E 06	0.26367399E 00
0.20109861E-04	0.37971418E 11	0.37677967E 04	0.24597295E-25		

XN(1) - XN(18)

0.26849996E-01	0.72098411E-02	0.90791864E-09	0.10002649E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10102499E-09	0.31560105E-06	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10002649E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.62649359E 03	0.11936375E 04	0.37464224E 04	0.61507607E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.34672732E 08	0.24064480E 09	0.19248067E 03	0.11329124E-06	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597295E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, continued

ICOUNT = 20

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.32509361E 02	0.81321424E 01	0.39912905E 00	0.22213746E 06	0.18341212E 06	0.26818592E 00
0.20329935E-04	0.38834929E 11	0.38224122E 04	0.24597293E-25		

XN(1) - XN(18)

0.26849993E-01	0.72094267E-02	0.52947858E-08	0.10096949E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.54309506E-09	0.11398468E-05	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10096949E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.77624863E 03	0.18987240E 04	0.37933071E 04	0.81989029E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.98828012E 08	0.59280691E 09	0.11422729E 04	0.45989512E-06	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597293E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, continued

ICOUNT = 23

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.32917087E 02	0.84756728E 01	0.93228296E 00	0.20773694E 06	0.17520612E 06	0.30630370E 00
0.18633673E-04	0.40306244E 11	0.38998087E 04	0.11275756E-19		

XN(1) - XN(18)

0.26849973E-01	0.72075344E-02	0.42536120E-07	0.14616900E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.30497802E-08	0.48871865E-05	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.14616900E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.98449739E 03	0.28631484E 04	0.38682669E 04	0.19836026E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.25284572E-09	0.11276221E 10	0.94307845E 04	0.99868974E-05	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597274E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, continued

ICOUNT = 31

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.34543679E 02	0.98461634E 01	0.30592636E 01	0.15028709E 06	0.20497404E 06	0.30123385E 00
0.16195612E-04	0.34647779E 11	0.32447281E 04	0.29514132E-11		

XN(1) - XN(18)

0.26849683E-01	0.71934713E-02	0.62031669E-06	0.35767629E-14	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.52540090E-08	0.32441152E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.35767629E-14	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.13415357E 04	0.35538891E 04	0.37242630E 04	0.36719100E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.91219459E 03	0.91219459E 03	0.91219459E 03	0.91219459E 03	0.91219459E 03	0.91219459E 03
0.91219459E 03	0.91219459E 03	0.91219459E 03	0.91219459E 03	0.91219459E 03	0.91219459E 03
0.91219459E 03	0.91219459E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.66259789E 09	0.15217369E 10	0.13041478E 06	0.66362685E-03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.35107104E-22	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, continued

ICOUN 37

X RHO	Y HSUM	S TT	P EFTT	U	A
0.37466533E 02	0.11636415E 02	0.64930832E 01	0.84463107E 05	0.23426162E 06	0.37798098E 00
0.11293509E-04	0.28217091E 11	0.26150049E 04	0.13589451E-10		

XN(1) - XN(18)

0.26849648E-01	0.71918744E-02	0.69437259E-06	0.36965762E-14	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.48555618E-09	0.35560629E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.36965762E-14	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.13809912E 04	0.31928267E 04	0.35280592E 04	0.36403116E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.94031582E 03	0.94031582E 03	0.94031582E 03	0.94031582E 03	0.94031582E 03	0.94031582E 03
0.94031582E 03	0.94031582E 03	0.94031582E 03	0.94031582E 03	0.94031582E 03	0.94031582E 03
0.94031582E 03	0.94031582E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.71665762E 09	0.13134013E 10	0.13517382E 06	0.67681507E-03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.36815970E-21	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, continued

Streamline No. 13, continued

ICOUNT = 41

X RHO	Y HSUM	S TT	P SETT	U	A
0.40963234E 02	0.13184028E 02	0.10322098E 02	0.45710234E 05	0.25062540E 06	0.55570748E 00
0.71800698E-05	0.24249769E 11	0.22259603E 04	0.17007481E-10		

XN(1) - XN(18)

0.26849645E-01	0.71917353E-02	0.69935570E-06	0.36979077E-14	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.67148738E-10	0.35833667E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.36979077E-14	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.13869847E 04	0.30293297E 04	0.34700642E 04	0.36357650E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.94670331E 03	0.94670331E 03	0.94670331E 03	0.94670331E 03	0.94670331E 03	0.94670331E 03
0.94670331E 03	0.94670331E 03	0.94670331E 03	0.94670331E 03	0.94670331E 03	0.94670331E 03
0.94670331E 03	0.94670331E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.72499587E 09	0.12197941E 10	0.13293649E 06	0.67575830E-03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.61582634E-21	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

ICOUNT = 50

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.51136229E 02	0.15531926E 02	0.20772542E 02	0.19514645E 05	0.26971776E 06	0.94274428E 00
0.39327519E-05	0.19282478E 11	0.17349874E 04	0.17660321E-10		

XN(1) - XN(18)

0.26849643E-01	0.71917000E-02	0.69963854E-06	0.36979183E-14	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.11719573E-11	0.35903498E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.36979183E-14	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.13879960E 04	0.29085705E 04	0.34404937E 04	0.36340612E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.94967642E 03	0.94967642E 03	0.94967642E 03	0.94967642E 03	0.94967642E 03	0.94967642E 03
0.94967642E 03	0.94967642E 03	0.94967642E 03	0.94967642E 03	0.94967642E 03	0.94967642E 03
0.94967642E 03	0.94967642E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.72640606E 09	0.11509615E 10	0.13135627E 06	0.67527292E-03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.73060003E-21	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, continued

ICOUNT = 54

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.65750667E 02	0.18105232E 02	0.35612258E 02	0.14345330E 05	0.27494657E 06	0.11574192E 01
0.31423967E-05	0.17858530E 11	0.15961791E 04	0.17748398E-10		

XN(1) - XN(18)

0.26849642E-01	0.71916885E-02	0.69964410E-06	0.36979180E-14	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.21730784E-12	0.35926440E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.36979180E-14	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.13881297E 04	0.28401984E 04	0.34266738E 04	0.36334539E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.95105511E 03	0.95105511E 03	0.95105511E 03	0.95105511E 03	0.95105511E 03	0.95105511E 03
0.95105511E 03	0.95105511E 03	0.95105511E 03	0.95105511E 03	0.95105511E 03	0.95105511E 03
0.95105511E 03	0.95105511E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.72659251E 09	0.11121146E 10	0.13059416E 06	0.67509920E-03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-30	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.87088283E-21	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, continued

ICOUNT = 62

X	Y	S	P	U	A
RHO	HSUM	TT	EETT		
0.15800000E 03	0.30572211E 02	0.15138176E 03	0.93263585E 04	0.28132430E 06	0.15586597E 01
0.22805597E-05	0.16084665E 11	0.14298897E 04	0.17799623E-10		

XN(1) - XN(18)

0.26849641E-01	0.71916707E-02	0.69964560E-06	0.36979176E-14	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.17001837E-13	0.35961632E-04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.36979176E-14	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.13882072E 04	0.26377102E 04	0.33892754E 04	0.36321297E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.95467002E 03	0.95467002E 03	0.95467002E 03	0.95467002E 03	0.95467002E 03	0.95467002E 03
0.95467002E 03	0.95467002E 03	0.95467002E 03	0.95467002E 03	0.95467002E 03	0.95467002E 03
0.95467002E 03	0.95467002E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.72670050E 09	0.99766827E 09	0.12853085E 06	0.67472039E-03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.11586008E-20	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 13, concluded

APPENDIX VI. Input-Output Data for RAM-B3,
Streamline No. 26

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ____ PROGRAMMER ____ DATE ____ PAGE ____ of ____ JOB NO. ____

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1 12	73 … 80	LPRNT LIMX
13	1 14		IND N1
25	37 13		N2 N3
37	1 7		N4 N5
49			
61			
1	1	73 … 80	
13	83140000E08		R
25	154.0		XSTOP
37	28.0		$W_1 - W_3$
49	32.0		
61	30.0		
1	446	73 … 80	
13	38.1		$TABX_1 - TABX_5$
25	40.1		
37	41.5		
49	44.4		
61	49.5		
1	451	73 … 80	
13	54.8		$TABX_6 - TABX_{10}$
25	60.8		
37	67.1		
49	75.8		
61	92.0		

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FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE____ of____ JOB NO.______

	NUMBER	IDENTIFICATION 73–80	DESCRIPTION DO NOT KEY PUNCH
1	456		
13	123.0		$TABX_{11,12}$
25	154.8		
37			
49			
61			
1	466		
13	13.71		$TABY_1 - TABY_5$
25	14.9		
37	15.6		
49	16.77		
61	18.5		
1	471		
13	19.8		$TABY_6 - TABY_{10}$
25	21.04		
37	22.2		
49	23.65		
61	26.2		
1	476		
13	30.48		$TABY_{11,12}$
25	34.82		
37			
49			
61			

Streamline No. 26, continued

FORM 116-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

Streamline No. 26, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	486		
13	106300000E06		$TABAP_1 - TABAP_5$
25	883000000E05		
37	740000000E05		
49	541000000E05	73 80	
61	333000000E05		
1	491		
13	226000000E05		$TABAP_6 - TABAP_{10}$
25	173500000E05		
37	154000000E05		
49	134600000E05	73 80	
61	11280000E05		
1	496		
13	962000000E04		$TABAP_{11,12}$
25	923000000E04		
37			
49		73 80	
61			
1	10097		
13	0.10000E-01		STEP
25	0.2105		A
37	1.0		COUNT
49	1.0	73 80	TAUADJ
61			UV

FORM 114-C-17 REV. 7-58-VELLUM

Streamline No. 26, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ________ PROGRAMMER ____________ DATE ________ PAGE ____ of ____ JOB NO. ________

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	-1.0102		
13	1.0630000E06		P
25	2073.0		TT
37	1.0		XMF
49	38.1	73 80	X
61	13.71		Y
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			

FORM 114-C-17 REV. 7-56- VELLUM

STARTING CONDITIONS ICOUNT = 1

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.38100000E 02	0.13710000E 02	0.00000000E-38	0.10630000E 06	0.26482262E 06	0.21050000E 02
0.17938776E-04	0.20654783E 11	0.20730000E 04	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72100000E-02	0.10000000E-11	0.10000000E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10000000E-11	0.10000000E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10000000E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26480000E 03	0.26480000E 03	0.26480000E 03	0.26480000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.22042162E 05	0.26986061E 06	0.78495267E-05	0.75777157E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 13

X / RHO	Y / HSUM	S / TT	P / EFTT	U	A
0.38170383E 02	0.13751878E 02	0.81900000E-01	0.10566655E 06	0.26494243E 06	0.21130748E 00
0.17862145E-04	0.20653038E 11	0.20694874E 04	0.24597297E-25		

XN(1) - XN(18)

0.26849998E-01	0.72099993E-02	0.12653196E-11	0.99999990E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.73516237E-12	0.16029049E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999990E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.30743060E 03	0.37798465E 03	0.10330326E 04	0.30350097E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.12900209E 06	0.34682602E 07	0.22169270E-01	0.38992455E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597297E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 15

X / RHO	Y / HSUM	S / TT	P / EFTT	U	A
0.38356568E 02	0.13862658E 02	0.29854980E 00	0.10399088E 06	0.26526643E 06	0.21347051E 00
0.17659557E-04	0.20567144E 11	0.20600338E 04	0.24597297E-25		

XN(1) - XN(18)

0.26849998E-01	0.72099952E-02	0.16717669E-11	0.99999988E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.32987077E-12	0.28273761E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999988E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.34294897E 03	0.47349837E 03	0.13282530E 04	0.33713184E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.40291971E 06	0.11630372E 08	0.56028870E-01	0.11882174E-08	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597297E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 21

X	Y	S	P	U	A
RHO	HSUM	TT	EETT		
0.39051275E 02	0.14276009E 02	0.11069286E 01	0.97738571E 05	0.26656912E 06	0.22190229E 00
0.16905514E-04	0.20220733E 11	0.20225361E 04	0.24597296E-25		

XN(1) - XN(18)

0.26849997E-01	0.72099988E-02	0.19852097E-11	0.99999983E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.19470564E-13	0.53717966E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999983E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.38931131E 03	0.62884205E 03	0.14574161E 04	0.38115705E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.12975486E 07	0.38478426E 08	0.82192532E-01	0.38052693E-08	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597296E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 34

X RHO	Y HSUM	S TT	P FFTT	U	A
0.40738322E 02	0.15219161E 02	0.30409175E 01	0.81779994E 05	0.27036356E 06	0.24768459E 00
0.14933199E-04	0.19202044E 11	0.19158132E 04	0.24597293E-25		

XN(1) - XN(18)

0.26849994E-01	0.72079981E-02	0.20072040E-11	0.99999973E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.64241392E-16	0.74575713E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999973E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.42627031E 03	0.79219717E 03	0.14709288E 04	0.41602078E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.27513464E 07	0.83223815E 08	0.84808205E-01	0.80318540E-08	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597293E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 48

X / RHO	Y / HSUM	S / TT	P / EFTT	U	A
0.44723529E 07	0.16879746E 02	0.73612590E 01	0.52780508E 05	0.27865232E 06	0.32724145E 00
0.10966525E-04	0.16926703E 11	0.16836955E 04	0.24597290E-25		

XN(1) - XN(18)

0.26849990E-01	0.72099973E-02	0.20076528E-11	0.99999961E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.15519569E-18	0.78151476E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999961E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.44564442E 03	0.90759608E 03	0.14758656E 04	0.43403893E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.38919868E 07	0.12283488E 09	0.85452353E-01	0.11274015E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597290E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 51

X	Y	S	P	U	A
RHO	HSUM	TT	EFTT		
0.47224522E 02	0.17726122E 02	0.10002226E 02	0.42580379E 05	0.28273800E 06	0.37227045E 06
0.95007362E-05	0.15779871E 11	0.15678745E 04	0.24597290E-25		

XN(1) - XN(18)

0.26849990E-01	0.72099971E-02	0.20076567E-11	0.99999959E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.41215694E-19	0.78196038E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999959E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.44866592E 03	0.93084393E 03	0.14764408E 04	0.43679976E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.40851521E 07	0.13146697E 09	0.85525438E-01	0.11845982E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597290E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 59

X	Y	S	P	U	A
RHO	HSUM	TT	EETT		
0.57261235E 02	0.20308655F 02	0.20375408F 02	0.20446419F 05	0.29258171F 06	0.61317287F 00
0.55740376E-05	0.12948229E 11	0.12832355E 04	0.24597290E-25		

XN(1) - XN(18)

0.26849990E-01	0.72099968E-02	0.20076569E-11	0.99999952E-16	0.00000000E-38	0.00000000E-39
0.00000000E-38	0.12304536E-20	0.78199655E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999952E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.45097202E 03	0.95281506E 03	0.14763209E 04	0.43886880E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.42454031E 07	0.13990454E 00	0.85510244E-01	0.12298564E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597290E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 64

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.68672219E 02	0.22462037E 02	0.31988765E 02	0.15049413E 05	0.29588734E 06	0.76108782E 00
0.44405713E-05	0.11975600E 11	0.11856042E 04	0.24597290E-25		

XN(1) - XN(18)

0.26849990E-01	0.72099968E-02	0.20076569E-11	0.99999948E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.14656111E-21	0.78199555E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999948E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.45129582E 03	0.95676761E 03	0.14760088E 04	0.43915026E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.42682664E 07	0.14132234E 09	0.85470678E-01	0.12349705E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

FE(1) - FE(18)

0.24597290E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, continued

ICOUNT = 78

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.15400000E 03	0.34314761E 02	0.13773337E 03	0.92754016E 04	0.30052724E 06	0.10733928E 01
0.30999698E-05	0.10591938E 11	0.10467290E 04	0.24597290E-25		

XN(1) - XN(18)

0.26849990E-01	0.72099968E-02	0.20076569E-11	0.99999936E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.48462599E-24	0.78199655E-11	0.00000000E-39	0.00000000E-38	0.00000000E-38
0.99999936E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.45177742E 03	0.96197057E 03	0.14747111E 04	0.63955926E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.43024393E 07	0.14332846E 09	0.85306226E-01	0.12438952E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597290E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 26, concluded

APPENDIX VII. Input-Output Data for [illegible]-33, Streamline No. 30

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE____ of____ JOB NO.______

Col.	NUMBER		IDENTIFICATION	DESCRIPTION	DO NOT KEY PUNCH
1	1	12		LPRNT	LIMX
13	1	14		IND	N1
25	37	13		N2	N3
37	1	7		N4	N5
49			73 80		
61					
1	446				
13	45.0			$TABX_1 - TABX_5$	
25	47.75				
37	51.5				
49	57.4		73 80		
61	67.0				
1	451				
13	74.1			$TABX_6 - TABX_{10}$	
25	85.2				
37	99.2				
49	114.1		73 80		
61	128.8				
1	456				
13	141.1			$TABX_{11,12}$	
25	154.5				
37					
49			73 80		
61					

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Streamline No. 30, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.____ PROGRAMMER____ DATE____ PAGE____of____ JOB NO.____

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	466		
13	17.98		$TABY_1 - TABY_5$
25	19.12		
37	20.34		
49	22.0		
61	24.0		
1	471		
13	25.35		$TABY_6 - TABY_{10}$
25	27.2		
37	29.15		
49	31.44		
61	33.6		
1	476		
13	35.0		$TABY_{11,12}$
25	37.0		
37			
49			
61			
1	486		
13	66000.0		$TABAP_1 - TABAP_5$
25	53304.0		
37	40100.0		
49	27350.0		
61	17230.0		

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Streamline No. 3P$_2$ continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	491.		
13	15120.0		TABAP$_6$ - TABAP$_{10}$
25	12900.0		
37	11280.0		
49	10990.0	73 80	
61	9580.0		
1	496		
13	9310.0		TABAP 11,13
25	9190.0		
37			
49		3 80	
61			
1	10097		
13	0.00001		STEP
25	0.2073		A
37	1.0		COUNT
49	1.0	73 80	TAUADJ
61			UV
1	-10102		
13	64000.0		P
25	1348.0		TT
37	1.0		XMF
49	45.0	73 80	X
61	17.98		Y

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STARTING CONDITIONS ICOUNT = 1

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.45000000E 02	0.17980000E 02	0.00000000E-38	0.64000000E 05	0.29043688E 06	0.20730000E 00
0.16609208E-04	0.13450699E 11	0.13480000E 04	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72100000E-02	0.10000000E-11	0.10000000F-15	0.00000000F-38	0.00000000E-38
0.00000000E-38	0.10000000E-11	0.10000000E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10000000E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26480000F 03	0.26480000E 03	0.26480000E 03	0.26480000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000F-38	0.00000000E-38	0.00000000F-38	0.00000000F-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.22042162E 05	0.26986061E 06	0.78495267E-05	0.75777157E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 30, continued

ICOUNT = 17

X RHO	Y HSUM	S TT	P EETT	U	A
0.46092689E 02	0.18432969E 02	0.11828572E 01	0.59748445E 05	0.29135531E 06	0.21691926E 00
0.15822640E-04	0.13183519E 11	0.13210113E 04	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72099991E-02	0.16757826E-11	0.99999987E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.32421714E-12	0.16757833E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999987E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.27839716E 03	0.35527579E 03	0.95146346E 03	0.27597065E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.41069881E 05	0.23663292E 07	0.23068801E-01	0.12736649E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 30, continued

ICOUNT = 23

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.49378770E 02	0.19649893E 02	0.46897266E 01	0.47566729E 05	0.29421705E 06	0.25258452E 00
0.13456292E-04	0.12345636E 11	0.12366213E 04	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72099987E-02	0.19764825E-11	0.99999982E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.23517269E-13	0.19764835E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999982E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.29274826E 03	0.42223023E 03	0.10121661E 04	0.28846388E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.74395481E 05	0.64968940E 07	0.32666636E-01	0.21706148E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 30, continued

ICOUNT = 29

X / RHO	Y / HSUM	S / TT	P / FETT	U	A
0.55349928E 02	0.2142320[illegible]E 02	0.10919800E 02	0.31780239E 05	0.29902492E 06	0.32889592E 00
0.10167967E-04	0.10919[illegible]E 11	0.10934071E 04	0.24597299E-25		
XN(1) - XN(18)					
0.26850000E-01	0.72099984E-02	0.19983259E-11	0.99999977E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.16736928E-14	0.19983271E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999977E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
TV(1) - TV(18)					
0.29817893E 03	0.45300843E 03	0.10145912E 04	0.29324831E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
TE(1) - TE(18)					
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
EV(1) - EV(18)					
0.91771775E 05	0.93600046E 07	0.33256068E-01	0.26304206E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
EE(1) - EE(18)					
0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-[illegible]
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-[illegible]
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 30, continued

ICOUN. 36

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.78265702E 02	0.26044284E 02	0.34305958E 02	0.14286859E 05	0.30609148E 06	0.57455217E 00
0.56861628E-05	0.87814753E 10	0.87897469E 03	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72099980E-02	0.19999071E-11	0.99999971E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.92393641E-16	0.19999083E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999971E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.29971097E 03	0.46743900 03	0.10145889E 04	0.29456796E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.97236530E 05	0.10928107E 08	0.33282169E-01	0.27705329E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 30, continued

ICOUNT = 42

X RHO	Y HSUM	S TT	P EETT	U	A
0.14958021E 03	0.36265702E 02	0.10635326E 03	0.92340577E 04	0.30938073E 06	0.77792384E 00
0.41549869E-05	0.77692520E 10	0.77746671E 03	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72099976E-02	0.19999921E-11	0.99999966E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.72892031E-17	0.19999933E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999966E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.29999146E 03	0.47285944E 03	0.10144966E 04	0.29479948E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.98265444E 05	0.11555047E 08	0.33274869E-01	0.27957395E-09	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 30, concluded

APPENDIX VIII. Input-Output Data for RAM-B3,
Streamline No. 34

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE____ of____ JOB NO.______

	NUMBER		IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH	
1	1	1.0		LPRNT	LIMX
13	1	1.4		IND	N1
25	37	1.3		N2	N3
37	1	7		N4	N5
49			73 80		
61					
1	446				
13	56.2			$TABX_1 - TABX_5$	
25	67.5				
37	74.1				
49	81.5		73 80		
61	91.8				
1	451				
13	102.0			$TABX_6 - TABX_{10}$	
25	112.0				
37	129.3				
49	143.5		73 80		
61	154.8				
1	446				
13	23.0			$TABY_1 - TABY_5$	
25	26.6				
37	28.05				
49	29.43		73 80		
61	31.2				

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FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ___ of ___ JOB NO. ______

Streamline No. 34, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	471	73–80	
13	32.83		$TABY_6 - TABY_{10}$
25	34.25		
37	36.68		
49	38.55		
61	20.0		
1	486	73–80	
13	39250.0		$TABAP_1 - TABAP_5$
25	26600.0		
37	20650.0		
49	16800.0		
61	14020.0		
1	491	73–80	
13	12380.0		$TABAP_6 - TABAP_{10}$
25	11200.0		
37	9980.0		
49	9410.0		
61	9160.0		
1	10097	73–80	
13	0.00001		STEP
25	0.2[illegible]1		A
37	1.0		COUNT
49	1.0		TAUADT
61			UV

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Streamline No. 34, continued

FORTRAN FIXED 10 — DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	-1.01.02		
13	39250.0		P
25	926.0		TT
37	1.0		XMF
49	56.2	73 80	X
61	23.0		Y
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			

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STARTING CONDITIONS ICOUNT = 1

X RHC	Y HSUM	S TT	P FETT	U	A
0.56200000E 02	0.23000000E 02	0.00000000E-38	0.39250000E 05	0.30515480E 06	0.22100000E 00
0.14828169E-04	0.92399634E 10	0.92600000E 03	0.24597299E-25		
XN(1) - XN(18)					
0.26850000E-01	0.72100000E-02	0.10000000E-11	0.10000000E-15	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.10000000E-11	0.10000000E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.10000000E-15	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
TV(1) - TV(18)					
0.26480000E 03	0.26480000E 03	0.26480000E 03	0.26480000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
TE(1) - TE(18)					
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
EV(1) - EV(18)					
0.22042162E 05	0.26966061E 06	0.78495267E-05	0.75777157E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
EE(1) - EE(18)					
0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 34, continued

ICCUNT = 2C

X	Y	S	P	U	A
RHC	HSUM	TT	FETT		
0.63653223E 02	0.25387221E 02	C.78643CCCE C1	0.30861569E 05	0.30723322E C6	0.25992372E 00
0.12522352E-C4	C.86035475E 1C	0.86216613E C3	0.24597299E-25		

XN(1) - XN(18)

C.2685CCCCE-C1	0.72C99989E-C2	C.17298488E-11	C.99999984E-16	0.00000000E-38	0.00000000E-38
0.CCC00000E-38	0.27015101E-12	0.17298488E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999984E-16	0.322C0000E-C2	0.00CC0CCCE-38	C.CCC00000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.2658C796E C3	0.2C301872E C3	C.70798814E C3	0.26553193E 03	0.00000000E-38	0.00000000E-38
0.C0CCCCC0E-38	0.CCCC0C00E-38	C.0CCCCCCCE-38	C.CCC00000E-38	0.00000000E-38	0.00000000E-38
0.C0000000E-38	0.0CCC0000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

C.400000C0E C3	0.4C0C000CE 03	C.4CC000C0E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40C00000E C3	0.4CC000C0E 03	C.4CCCCCCCE C3	C.4C000000E 03	0.40000000E 03	0.40000000E 03
0.400000C0E C3	0.4CCC0CCCE C3	C.0CC000C0E-38	C.CC000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.23133338E C5	C.79064C44E C6	C.85855639E-C2	0.785C4698E-10	0.00000000E-38	0.00000000E-38
0.C0000000E-38	C.0C000000E-38	C.C0C0CCC0E-38	0.0C000000E-38	0.00000000E-38	0.00000000E-38
0.00000C0CE-38	0.CCCC0CCCE-38	C.00C00000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.0CCC0000E-38	C.C0CCCCCCE-38	C.CCCC0000E-38	0.00000000E-38	0.00000000E-38
C.C0C00CCCE-38	C.0CCC0000E-38	C.00C0CCCCE-38	0.0C000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.0000000CE-38	C.CCC00000E-38	0.0C000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 34, continued

ICCUNT = 22

X / RHC	Y / HSUM	S / TT	P / EETT	U	A
0.72542156E 02	0.27707746E C2	C.17C22CC2E C2	0.22054420E 05	0.30973384E C6	0.32842276E 00
C.98305563E-C5	0.78321468E 1C	0.78483147E C3	0.24597299E-25		

XN(1) - XN(18)

0.2685C0C0E-C1	0.72C99588E-C2	0.1884C452E-11	C.99999983E-16	0.00000000E-38	0.00000000E-38
C.CCC0CCC0E-38	0.11595454E-12	C.1884C452E-11	C.CC000000E-98	0.00000000E-38	0.00000000E-38
0.99999983E-16	0.322C0CC0E-03	0.00CC0CCCE-38	0.CC000000E-38	0.C000C000E-38	0.00000000E-38

TV(1) - TV(18)

0.2661456CE C3	0.31452523E C3	C.71985756E C3	0.26577458E 03	0.00000000F-38	0.00000000E-38
0.COC000CCE-38	0.00000000E-38	C.CCC00000E-38	C.00000000F-38	0.00000000E-38	C.00000000E-38
C.00C000C0E-38	0.0C000000E-38	C.CCC0CCCCE-38	0.0C000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

C.400000C0E 03	0.40000CCCE C3	C.4CCCCCCCE C3	C.4C000000E 03	C.4CC00000E 03	0.40000000E 03
0.4C000CC0E C3	0.4CCC0C0CE 03	C.4CCCCCCCE C3	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40C000C0E C3	0.4CCC0C00E 03	C.0C0C0CCCE-38	0.0C000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.23508875E C5	0.1C383574E C7	C.59786338E-C2	0.79427011F-10	0.000000C0F-38	0.00000000F-38
0.COCC0CC0E-38	0.00000000E-38	C.00C00CCCE-38	0.00000000E-38	C.00000000F-38	0.00000000E-38
C.COC000C0E-38	C.CCCC0C0CE-38	C.CCCCCCCCE-38	0.0C000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

C.24597299E-25	0.0C0C0C0CE-38	C.0CCCCCCCE-38	C.CC000000E-38	C.0C000000F-38	0.00000000F-38
C.COC0CCCCE-38	0.CCCC0C0CE-38	C.C0CCCCCCE-38	C.CCC00000E-38	C.0CCC0C00E-38	0.000C0C0CE-38
0.C00000C0E-38	0.0CC00000E-38	C.0CC00000E-38	C.0C000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 34, continued

ICCUNT = 24

X RHC	Y FSUM	S TT	P FETT	U	A
0.93676696E 02	0.31459903E 02	0.38496058E 02	0.13718257E 05	0.31290161E 06	0.45682200E 00
0.69999259E-05	0.68459610E 10	0.68598180E 03	0.24597299E-25		

XN(1) - XN(18)

0.26850000E-01	0.72099987E-02	0.19457791E-11	0.99999981E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.54220558E-13	0.19457792E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999981E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26625957E 03	0.32019542E 03	0.72061150E 03	0.26585450E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.22636791E 05	0.11791128E 07	0.10345123E-01	0.79732794E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 34, continued

ICCUNT = 26

X RHC	Y FSUM	S TT	P EETT	U	A
C.1580CCC0E-03	0.37769402E 02	C.10381936E C3	0.96479363E 04	0.31534193E 06	0.57233185E CC
0.55407721E-C5	C.6C793944E 1C	0.20514814E C3	0.24597299E-25		

XN(1) - XN(18)

0.2685CCC0E-C1	0.72099986E-C2	C.19745241E-11	0.59999979E-16	0.0000C000E-38	0.0000000CE-38
0.COCOCOC0E-38	0.25475563E-13	C.19745241E-11	0.0C000000E-38	0.00000000F-38	0.00000000E-38
0.59999979E-16	0.32200C00E-03	C.00C00CCCE-38	C.0C0C0000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26629509E C3	0.32332903E C3	C.71965121E 03	0.26587860E 03	0.00000000E-38	0.00000000E-38
C.COCOCCCCE-38	0.0C000C00E-38	C.00COCCCCE-38	C.CC000000E-38	C.00000000E-38	0.00000000E-38
0.00000000E-38	C.CCCC0000E-38	0.00C000CCE-38	C.0C000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

C.4CC0CCCCE C3	0.4CCCOCCCE 03	C.4CCCCCCCE C3	0.40000000E 03	0.40000000F 03	0.40000000E 03
C.40000CCCE C3	C.4CCC0000E 03	C.40COCCCCE C3	0.40000000E 03	0.40000000E 03	0.40000000E 03
C.40COCCC0E C3	0.4CCCOCCCE C3	C.COCCOC0CE-38	0.0C000000E-38	0.00000000F-38	0.00000000E-38

EV(1) - EV(18)

0.23676766E C5	0.12625188E C7	C.10443995E-C1	C.79825168E-10	0.00000000F-38	0.0000000CE-38
0.C0000000E-38	C.CCCC0000E-38	0.00C000CCE-38	0.0CC00000E-38	0.00000000E-38	0.0000000CE-38
C.COC00000E-38	0.0C0C0000E-38	C.0CC000CCE-38	C.CC000000E-38	C.00000000E-38	0.0000000CE-38

EE(1) - EE(18)

0.24597299E-25	C.CCCC0000E-38	C.COCOCCCCE-38	C.CC000000E-38	C.00000000E-38	C.CCCCOC00E-38
0.C0000000E-38	C.0C000COCE-38	0.00CC00CCE-38	C.0C000C00E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.0C0C0C0CE-38	C.CCCC00C0E-38	C.CCCC0C00E-38	0.00000000E-38	0.00000000E-38

Streamline No. 34, concluded

APPENDIX IX. Input-Output Data for RAM-B3, Streamline No. 36

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ___ of ___ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1 8	73 – 80	IPRNT LIMX
13	1 14		IND N1
25	37 13		N2 N3
37	1 7		N4 N5
49			
61			
1	446	73 – 80	
13	71.3		$TABX_1$ – $TABX_5$
25	85.0		
37	97.1		
49	107.1		
61	118.7		
1	451	73 – 80	
13	133.8		$TABX_6$ – $TABX_8$
25	147.7		
37	158.0		
49			
61			
1	466	73 – 80	
13	28.18		$TABY_1$ – $TABY_5$
25	31.8		
37	34.35		
49	36.05		
61	37.82		

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Streamline No. 36, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE____ of____ JOB NO.______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	471	73–80	
13	39.88		$TABY_6 - TABY_9$
25	41.65		
37	43.05		
49			
61			
1	486	73–80	
13	26000.0		$TABAP_1 - TABAP_5$
25	19000.0		
37	15520.0		
49	13640.0		
61	12030.0		
1	491	73–80	
13	10580.0		$TABAP_6 - TABAP_8$
25	9720.0		
37	9325.0		
49			
61			
1	10097	73–80	
13	0.00001		STEP
25	0.2455		A
37	1.0		COUNT
49	1.0		TAUADJ
61			UV

FORM 114-C-17 REV. 7-58-VELLUM

Streamline No. 36, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE____ of____ JOB NO.______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	-1.01.02		
13	26000.0		P
25	698.0		TT
37	1.0		XAAF
49	71.3	73 80	X
61	28.18		Y
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			

FORM 1??-C-17 REV. 7-59-VELLUM

STARTING CCNCITICNS ICCUNT = 1

X / RHC	Y / I-SUM	S / TT	P / EETT	U	A
C.712CCCCOE C2	0.2E18CCCCE C2	C.CCCCCCCCOE-30	C.26CCOCCOE 05	0.31258759E C6	0.2455CCCCE 0C
C.13030971E-C4	0.65649686E 1C	C.658CCOCOE C3	0.24597299E-25		

XN(1) - XN(1E)

0.26850CCCE-C1	0.721COCCCE-C2	C.10COOCCCE-11	C.1CCCOCOOE-15	C.00000000E-38	0.0000000CE-3E
C.CCCCOCCOE-38	0.1CCCCCOCE-11	C.1CCCCCCCE-11	C.0CCCOOOOE-38	C.COCCCOOOE-38	0.000COCOOE-3E
0.1CCOOCCCE-15	0.322COOOCE-02	C.COCOCCCCE-38	C.0COOOOOOE-38	C.000C0000E-38	0.00000COOE-38

TV(1) - TV(1E)

0.2648CCCCE C3	0.2648CCCCE C3	C.2648CCCOE C3	C.26480000E 03	C.0CCCCOC0E-38	0.000COCCCE-3E
C.CCCOOOOOE-38	0.0CCCOOOCE-3E	C.COCOCCCCE-38	C.CCCOOOOCE-38	C.C0000000E-38	0.00C00000E-38
0.C00000COE-38	0.0CCCOOOOE-38	C.00COOOCCE-38	C.0COOOOOOE-38	C.00000000E-38	0.0C000000E-38

TE(1) - TE(1E)

C.4CCOOCCCE C3	0.4CCCOCCCE C3	C.40CCOOCCE C3	C.4CCCOOOOE 03	C.COCOOOOOE-38	0.COCCOCOCE-3E
C.CCCOOCCOE-38	0.4CCOOCCCE 03	C.4CCCCCCCE C3	C.CCCCOOOOE-38	C.0COCOCOOE-38	0.00000000E-38
0.4CCOCCCCE C3	0.4CCCOCOCE C3	C.00COOOCCE-38	C.CCOOOOOOE-38	0.0OCCOOOOE-38	0.000CCCOOE-38

EV(1) - EV(1E)

0.22042162E C5	0.26566C61E C6	0.78495267E-C5	0.75777157E-1C	0.00000000E-38	0.00000COCE-3E
0.CCOOOCOOE-38	C.000COCOCE-3E	C.CCCCCCCCE-38	C.0COCOOOOE-38	C.00000000E-38	0.00000000E-38
C.CCCOOOOOE-38	C.CCCCOCOCE-38	C.000000CCE-38	C.0C000000E-38	C.00CCCOOOE-38	0.000COCOOE-38

EE(1) - EE(1E)

C.24597299E-25	0.CCCCCCCCE-38	C.CCCCCOCCE-3E	C.CCCCOOOOE-38	C.00CCCOOOE-38	C.COOCOCOCE-3E
0.C0000000E-38	0.0C000000E-38	C.CCCCCCCCE-38	C.0C000000E-38	0.00000000E-38	0.00000C000E-3E
C.CCCOOOCOE-38	C.CCOCOCOOE-38	C.00COOOCCE-38	C.0COOOOOOE-38	C.0OCCOOOOE-38	C.00000COOE-38

Streamline No. 36, continued

ICCUNT = 21

X / RMC	Y / HSUM	S / TT	P / EETT	U	A
0.91655125E C2	0.33702526E C2	C.20571SCCF C2	0.17C85964E 05	0.31502880E 06	0.32990885E 0C
0.96217E77E-C5	0.61588625E 1C	C.62121593E C3	C.24597299E-25		

XN(1) - XN(1E)

C.2685CCCCE-C1	C.72C5598EE-C2	C.1418C1C9E-11	C.59999983E-16	0.000CCCCCE-38	0.00000CCCE-38
0.C0C00000E-38	0.58198623E-12	C.1418C115E-11	C.CC000000E-38	C.00C0C000E-38	0.00000000E-38
0.59999983E-16	0.322C00C0E-C3	C.CCC0CCCCE-38	C.CC000000E-38	C.00000000F-38	C.00000000E-38

TV(1) - TV(1E)

0.26483556E C3	0.272C7787E C3	C.5150E243E C3	C.26482391E 03	C.C0000000F-38	0.00000000E-38
0.C0C0C000E-38	C.CCC00CCCE-38	C.CCC0C0CCE-38	C.CC000000E-38	0.00000000F-38	0.000C0000E-38
C.CCCCCCC0E-38	0.00000000E-38	C.C0C0C0CCE-3E	C.CCC00000E-38	0.000CCCCCE-38	0.00000000E-38

TE(1) - TE(1E)

C.4CC00CCCE C3	C.4CCC0CCCE C3	C.4CCCCCCCE C3	C.4CCC0C00E 03	C.40CCCCC0E 03	0.4C000C0CE C3
0.4CC00CC0E 03	C.4CCC0C0CE C3	C.4CCCCCCCE C3	C.4C0C0000E 03	0.40000000E 03	0.40000000E 03
C.40CCCCCCE C3	0.400000CCE 03	C.0CCC0CCCE-38	C.CCC00000E-38	C.C0CCCC00E-38	0.00000000E-38

EV(1) - EV(1E)

C.22C79902E C5	0.33854913E C6	C.164278C5E-C2	C.73864954E-1C	C.C0CCC000E-38	C.0000000CE-38
C.C0000CCCE-38	0.00000000E-38	C.CCCC00CCE-38	C.0C000000E-38	0.00000000E-38	C.00000000E-38
C.C0000CCCE-38	0.0CCC0C0CE-3E	C.CCCCCCCCE-3E	C.CCC00000E-38	C.00000000E-38	0.00000000E-38

EE(1) - EE(1E)

0.24597299E-25	C.0CCCCCCCE-38	C.0CCCCCCCE-38	C.0CCC0000E-38	C.00000000E-38	0.0000000CE-38
0.C0000000E-38	0.0C0C0000E-3E	C.CCCCCCCCE-38	C.C0000000E-38	0.00000000E-38	0.00000000E-38
C.CCCCCC0CE-38	C.CC0C0C0CE-3E	C.0C000CCCE-38	C.0C000000E-38	C.C0C0C000E-38	0.00000000E-38

Streamline No. 36, continued

ICOUNT = 24

X RHO	Y H-SUM	S TT	P EETT	U	A
0.15800000E 03	0.42487767E 02	0.14708904E 03	0.94836300E 04	0.31685415E 06	0.53596402E 00
0.58885038E-05	0.56221925E 10	0.56341515E 03	0.24597299E-25		

XN(1) - XN(18)

0.26650000E-01	0.72099987E-02	0.17097796E-11	0.99999981E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.29021888E-12	0.17097808E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999981E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26484743E 03	0.27662282E 03	0.52656293E 03	0.26483160E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.22092516E 05	0.38843317E 06	0.22237976E-02	0.75893247E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 36, concluded

APPENDIX X. Input-Output Data for RAM-B3, Streamline No. 38

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1 10		IPRNT LIMX
13	1 14		IND N1
25	37 13		N2 N3
37	1 7		N4 N5
49		73 80	
61			
1	446		
13	106.3		$TABX_1 - TABX_5$
25	112.0		
37	116.0		
49	121.2	73 80	
61	126.2		
1	451		
13	133.7		$TABX_6 - TABX_{10}$
25	139.1		
37	145.5		
49	150.0	73 80	
61	154.7		
1	466		
13	37.62		$TABY_1 - TABY_5$
25	38.8		
37	39.4		
49	40.25	73 80	
61	41.0		

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.____ PROGRAMMER____ DATE____ PAGE____ of____ JOB NO.____

Streamline No. 30, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	471		
13	42.0		$TABY_6 - TABY_{10}$
25	42.85		
37	43.6		
49	44.2	73 80	
61	44.8		
1	486		
13	15500.0		$TABAP_1 - TABAP_5$
25	14900.0		
37	14220.0		
49	13380.0	73 80	
61	12670.0		
1	491		
13	11820.0		$TABAP_6 - TABAP_{10}$
25	11270.0		
37	10700.0		
49	10400.0	73 80	
61	10100.0		
1	1.0097		
13	0.000021		STEP
25	0.2985		A
37	1.0		COUNT
49	1.0	73 80	TAUADJ
61			UV

FORM 114-C-17 REV. 7-38-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	-.10102		
13	15500.0		P
25	515.0		TT
37	1.0		XMF
49	106.3	73 80	X
61	37.621		Y
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			

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Streamline No. 38, continued

STARTING CCNCITICNS ICCUNT = 1

X RHC	Y HSUM	S TT	P EETT	U	A
0.1C630CCCE C3	0.3762CCCCE C2	C.CCCCCCCCE-38	C.155CCCCCE 05	C.31817561F 06	0.2985CCCCE CC
C.10528SC8E-04	0.51389E6CE 1C	C.51500CCCE C3	0.24597299E-25		

XN(1) - XN(18)

C.2665CCCCE-01	0.721CC0CCE-C2	C.1CCCCCCCE-11	C.1CCC0000E-15	0.00C0CCCCF-38	0.00000000E-38
0.C0000CCCE-38	C.1CCC0CCCE-11	C.10CCCCCCE-11	C.0C0000C00E-38	0.00000000E-38	0.000C0C0CE-38
0.10C00000E-15	0.322C0CCCE-C3	C.CCCC0CCCE-38	C.CCCC0C00F-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

C.2648CCCCE C3	0.2648CCCCE C3	C.2648CCCCE C3	C.26480000E 03	0.00C0CCCCF-38	0.000CCCCCE-38
C.C0000000E-38	0.CCC00000E-38	C.00CCCCC0E-38	C.CCC00000E-38	0.00C00000E-38	C.00000000F-38
0.C0000000E-38	0.0C0C0C0CE-38	C.CCCCCCC0CE-38	C.CCCCCCC0E-38	C.00000000E-38	0.000C0000E-38

TE(1) - TE(18)

C.4CCCCCCCE C3	C.4CCCCCCCF C3	C.4CCCCCCCF C3	C.40000000E 03	C.0CC000CCE-38	0.00CCCC0CE-38
0.CC000000E-38	0.4CCC0C00E 03	C.40C00CCCE C3	C.CC000000E-38	0.00CC0000E-38	0.00000C0CE-38
C.40C0000CE C3	0.4CCC0CCCE C3	C.CCCC0CCCE-38	C.CC000000E-38	C.00000000E-38	0.00000C0CE-38

EV(1) - EV(18)

0.22C42162E C5	C.26986C61E 06	C.78495267E-C5	C.75777157E-1C	C.00C00000E-38	C.CCCCCC0CE-38
C.C0000000E-38	0.CC000000E-38	0.C0C00CCCE-38	C.0C000000E-38	0.C0000000E-38	0.00000600E-38
C.C0C00000E-38	0.0000C000CE-38	C.00000000E-38	C.CC0C0000E-38	0.0000C0C0E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	C.CCCCCCCCE-38	C.CCCC0000E-38	C.CCCC0000E-38	C.00CC0000E-38	0.0CCCCC0CE-38
C.C0C00C00E-38	0.C00C0000E-38	C.00CCCCCCE-38	C.CC000000E-38	0.00000000E-38	0.00000000E-38
0.C0C000C00E-38	0.CC000000F-38	0.000000CCCE-38	C.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 38, continued

ICCLAT = 21

X RHC	Y HSUM	S TT	P FETT	U	A
0.12697409E 03 0.89943E59E-05	0.41103212E 02 0.48833528E 1C	C.20571900E 02 C.48938013E 03	C.12582270E 05 0.24597299E-25	0.31898199E 06	0.34854778E CC

XN(1) - XN(18)

0.2685CCCCE-C1	C.72059990E-02	C.10672829E-11	C.59999983E-16	0.0000C000E-38	C.0000C00CE-38
0.CCCCCCCCE-38	0.93271666E-12	C.10 72831E-11	C.C00CCC0CE-38	0.00000000F-38	0.00000000E-38
0.59999983E-16	0.322C0CCCE-C3	C.CCCC000CE-38	C.CCC00000E-38	C.0CC00000E-38	0.00000000E-38

TV(1) - TV(18)

0.264ECC36E C3	0.26517307E C3	C.33766C52E C3	C.26480021E 03	0.00CC00C0E-38	0.000C0CCCE-38
0.C0000000E-38	0.CCCC000CE-38	C.00C000C0E-38	0.CCCC0000F-38	0.00000000E-38	0.00000000E-38
C.00000000E-38	C.0CCC0CCCE-38	C.CCC0000CE-38	C.CC000000E-38	C.00000000E-38	0.0C0C0000E-38

TE(1) - TE(18)

C.4CCCCCCCE C3	C.4CCCCCCCE C3	C.4CCCCCCCE C3	0.4CCC0000E 03	C.40CCCCC0F C3	C.40CCCCCCF 03
0.40C00000E 03	0.4CCC0CCCE 03	C.40C000C0E C3	C.4CCC0C00F 03	0.40000000E 03	0.40000000F 03
C.40C000CCE C3	0.40CC0CCCE C3	0.00C0000CE-38	C.CCCC0000E-38	C.00000000E-38	C.0000000CE-38

EV(1) - EV(18)

0.22042544E C5	C.27311534F C6	C.76E24441E-C4	C.75777930E-1C	C.00000000E-38	C.C0C0CCCCE-38
C.00000000E-38	0.CCCC0C0CE-38	0.0000000CE-38	C.CCCC0000E-38	0.00000000F-38	0.00000000E-38
0.CCC0CC0CE-38	C.CCCC0CCCE-38	0.0CC0C0C0E-38	C.CCC00000E-38	C.0GCCC0C0E-38	C.0000000CE-38

EE(1) - EE(18)

C.24597299E-25	C.CCCCCC0CE-38	C.C0CCC0CCE-38	C.CCCC0000E-38	C.00C0C0C0E-38	C.CCCCCCCCE-38
0.C0000000E-38	0.CCCC0000E-38	C.0CC00CCCE-38	C.0CC00000E-38	0.00000C00F-38	0.00000000E-38
C.C0000000E-38	C.CCCC0C0CE-38	C.0CC000C0F-38	C.CC00000F-38	C.00000000F-38	0.00000C0CE-38

Streamline No. 38, continued

ICOUNT = 23

X RHO	Y FSUM	S TT	P RETT	U	A
0.15400000E 03	0.43900778E 02	0.83886060E 02	0.10549611E 05	0.31956791E 06	0.39905242E 00
0.78416395E-05	0.46963637E 10	0.47063954E 03	0.24597299E-25		

XN(1) - XN(18)

0.26650000E-01	0.72099959E-02	0.11763298E-11	0.99999982E-16	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.82367323E-12	0.11763265E-11	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.99999982E-16	0.32200000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26480075E 03	0.26571225E 03	0.36661065E 03	0.26480046E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03	0.40000000E 03
0.40000000E 03	0.40000000E 03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.22042964E 05	0.27787218E 06	0.15996499E-03	0.75778823E-10	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.24597299E-25	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Streamline No. 38, concluded

APPENDIX XI. Input-Output Data for the Hypersonic Nozzle Case

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ___ of ___ JOB NO. ______

Col.	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1 15		LPRNT LIMX
13	0 14		IND N1
25	37 13		N2 N3
37	14 7		N4 N5
49		73 … 80	
61			
1	426		
13	0.025189		$XN_1 - XN_5$
25	0.18328E-02		
37	0.340073E-02		
49	0.49600E-06	73 … 80	
61			
1	431		
13			$XN_6 - XN_{10}$
25			
37	0.12630E-03		
49	0.73890E-02	73 … 80	
61			
1	436		
13			$XN_{11} - XN_{14}$
25			
37	0.49600E-06		
49	0.32263E-03	73 … 80	
61			

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Hypersonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.____ PROGRAMMER____ DATE____ PAGE____ of____ JOB NO.____

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	446	73–80	
13	1.783		$TABX_1 - TABX_5$
25	5.08		
37	7.63		
49	10.18		
61	12.72		
1	451	73–80	
13	15.25		$TABX_6 - TABX_{10}$
25	19.68		
37	25.4		
49	38.1		
61	50.8		
1	456	73–80	
13	63.5		$TABX_{11} - TABX_{15}$
25	76.2		
37	89.0		
49	101.5		
61	123.0		
1	486	73–80	
13	0.1855		$TABAP_1 - TABAP_5$
25	1.928		
37	4.44		
49	7.99		
61	12.59		

FORM 114-C-17 REV. 7-58-VELLUM

Hyparsonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE____ of____ JOB NO.______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	491		
13	18.18		TABAP6 - TABAP10
25	28.2		
37	48.3		
49	93.9	73 80	
61	139.0		
1	496		
13	179.8		TABAP11 - TABAP15
25	214.8		
37	243.0		
49	263.5	73 80	
61	280.0		
1	506		
13	4982.0		TE1 - TE5
25	4982.0		
37	4982.0		
49	4982.0	73 80	
61			
1	511		
13			TE6 - TE10
25			
37	4982.0		
49	4982.0	73 80	
61			

FORM 114-C-17 REV. 7-58-VELLUM

Hypersonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	516		
13			TE_{11} - TE_{16}
25			
37	4982.0		
49	4982.0		
61			
1	526		
13	4982.6		TV_1 - TV_6
25	4982.0		
37	4982.0		
49	4982.0		
61			
1	8596		
13	1.0		XMU_1 - XMU_5 FOR N2
25	1.0		
37			
49	1.0		
61			
1	8606		
13			XMU_{11} - XMU_{15} FOR N_2
25			
37			
49	216.0		
61			

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Hypersonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ___ of ___ JOB NO. ______

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	8646		
13	1.0		$XMU_1 - XMU_5$ FOR O_2
25	1.0		
37			
49	1.0		
61			
1	8656		
13			$XMU_{11} - XMU_{15}$ FOR O_2
25			
37			
49	855.0		
61			
1	8696		
13	1.0		$XMU_1 - XMU_5$ FOR NO
25	1.0		
37			
49	1.0		
61			
1	8706		
13			$XMU_{11} - XMU_{15}$ FOR NO
25			
37			
49	1.0		
61			

FORM 116-C-17 REV. 7-58 VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ___ of ___ JOB NO. ______

Hypersonic Nozzle Case, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	8946		
13	1.0		$XMU_1 - XMU_5$ FOR N
25			
37			
49	1.0	73 80	
61			
1	8956		
13			$XMU_{11} - XMU_{15}$ FOR N
25			
37			
49	5.9	73 80	
61			
1	8996		
13	1.0		$XMU_1 - XMU_5$ FOR O
25	1.0		
37			
49	1.0	73 80	
61			
1	9006		
13			$XMU_{11} - XMU_{15}$ FOR O
25			
37			
49	5.9	73 80	
61			

FORM 114-C-57 REV. 7-58-VELLUM

Hypersonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.________ PROGRAMMER________________ DATE________ PAGE_____ of_____ JOB NO.________

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	9246		
13	1.0		XMU_1 - XMU_6 FOR Ar
25	1.0		
37			
49	1.0		
61			
1	9256		
13			XMU_{11} - XMU_{16} FOR Ar
25			
37			
49	5.9		
61			
1	966		
13	2170000000E14		FA_1 - FA_5
25	3920000000E14		
37	3920000000E14		
49	1325000000E14		
61	0.602		
1	9641		
13	6750000000E08		FA_6 - FA_{10}
25	8440000000E08		
37			
49			
61			

FORM 114-C-17 REV. 7-58-VELLUM

Hypersonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

Field	Sign	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1		9646		
13				$FA_1 - FA_{15}$
25				
37				
49		20200000E10		
61		16880000E26		
1		9651		
13				$FA_{16} - FA_{20}$
25				
37				
49				
61		45100000E05		
1		9686		
13	−	1.0		$FB_1 - FB_5$
25	−	1.0		
37	−	1.0		
49	−	1.0		
61		2.0		
1		9691		
13		0.0		$FB_6 - FB_{10}$
25	−	0.5		
37				
49				
61				

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ___ of ___ JOB NO. ______

Hypersonic Nozzle Case, continued

Col.	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	9696		
13			$FB_{11} - FB_{15}$
25			
37			
49	-1.0		
61	-3.0		
1	9701		
13			$FB_{16} - FB_{20}$
25			
37			
49			
61	0.5		
1	9736		
13	59.4		$FC_1 - FC_5$
25	113.1		
37	113.1		
49	75.6		
61	19.4		
1	9741		
13	37.5		$FC_6 - FC_{10}$
25	61.6		
37			
49			
61			

FORM 114-C-17 REV. 7-58-VELLUM

Hypersonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ___ of ___ JOB NO. ______

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	9746	73 … 80	
13			$FC_{11} - FC_{15}$
25			
37			
49	107.9		
61	107.9		
1	9751	73 … 80	
13			$FC_{16} - FC_{20}$
25			
37			
49			
61	32.4		
1	9786	73 … 80	
13	18130000E11		$BA_1 - BA_5$
25	21800000E13		
37	21800000E13		
49	32600000E13		
61	180.7		
1	9791	73 … 80	
13	15030000E09		$BA_6 - BA_{10}$
25	10200000E05		
37			
49			
61			

FORM 114-C-17 REV. 7-58-VELLUM

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ______ PROGRAMMER ______ DATE ______ PAGE ____ of ____ JOB NO. ______

Hypersonic Nozzle Case, continued

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	9796		
13			$BA_{11} - BA_{15}$
25			
37			
49	1.0170000E19	73 80	
61	8.3500000E34		
1	9801		
13			$BA_{16} - BA_{20}$
25			
37			
49		73 80	
61	9.0000000E14		
1	9836		
13	-0.5		$BB_1 - BB_5$
25	-1.0		
37	-1.0		
49	-1.0	73 80	
61	1.5		
1	9846		
13			$BB_{11} - BB_{15}$
25			
37			
49	-2.5	73 80	
61	-0.5		

FORM 114-C-17 REV. 7-58- VELLUM.

Hypersonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. ________ PROGRAMMER ________ DATE ________ PAGE ____ of ____ JOB NO. ________

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	9.851		
13			$BB_{16} - BB_{20}$
25			
37			
49		73 80	
61	-1.0		
1	9.886		
13			$BC_1 - BC_5$
25			
37			
49		73 80	
61	3.3		
1	9.891		
13			$BC_6 - BC_{10}$
25	40.0		
37			
49		73 80	
61			
1	1.0097		
13	0.00001		STEP
25	0.1855		A
37	1.0		COUNT
49	15.0	73 80	TRUADJ
61			UV

FORM 114-C-17 REV. 7-58-VELLUM

Hypersonic Nozzle Case, continued

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO.______ PROGRAMMER______ DATE______ PAGE___ of___ JOB NO.______

	NUMBER	IDENTIFICATION (73–80)	DESCRIPTION DO NOT KEY PUNCH
1	-101.02		
13	6.04000000E08		P
25	4982.0		TT
37	118.2		XME
49	1.783		X
61	0.0		Y
1			
13			
25			
37			
49			
61			
1			
13			
25			
37			
49			
61			
1			
13			
25			
37			
49			
61			

FORM 114-C-17 REV. 7-58-VELLUM

STARTING CONDITIONS ICOUNT = 1

X	Y	S	P	J	A
RHO	HSUM	TT	EETT		
0.17830000E 01	0.00000000E-38	0.00000000E-38	0.60400000E 08	0.16721929E 06	0.18550000E 00
0.38105458E-02	0.83400601E 11	0.49820000E 04	0.29189944E 06		

XN(1) - XN(18)

0.25189000E-01	0.18328000E-02	0.34073000E-02	0.49600000E-06	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.12630000E-03	0.73890000E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.49600000E-06	0.32763000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.49820000E 04	0.49820000E 04	0.49820000E 04	0.49820000E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49820000E 04	0.49820000E 04	0.49820000E 04	0.49820000E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.49820000E 04	0.49820000E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.49820000E 04	0.49820000E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.72961912E 10	0.60912796E 09	0.10610425E 10	0.14330185E 06	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.29189944E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

ICOUNT = 114

X RHO	Y HSUM	S TT	P EFTT	J	A
0.18236338E 01	0.00000000E-38	0.40633847E-01	0.48183308E 08	0.18288218E 06	0.20697542E 00
0.31276787E-02	0.80650276E 11	0.48117365E 04	0.18464374E 06		

XN(1) - XN(18)

0.26309390E-01	0.25543285E-02	0.12619749E-02	0.23515660E-06	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.31653243E-04	0.80902386E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.23515661E-06	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.48182118E 04	0.48147977E 04	0.48130186E 04	0.48182008E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49822117E 04	0.49822117E 04	0.49822117E 04	0.49822117E 04	0.49822117E 04	0.49822117E 04
0.49822117E 04	0.49822117E 04	0.49822117E 04	0.49822117E 04	0.49822117E 04	0.49822117E 04
0.49822117E 04	0.49822117E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.73762858E 10	0.80153201E 09	0.37570264E 09	0.64863113E 05	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.30507433E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

ICOUNT = 637

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.18913661E 01	0.00000000E-38	0.10836612E 00	0.35965371E 08	0.19993262E 06	0.24277266E 00
0.24351956E-02	0.77383636E 11	0.46727438E 04	0.99405076E 05		

XN(1) - XN(18)

0.26348502E-01	0.27784382E-02	0.11918474E-02	0.16979191E-06	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.23431475E-04	0.78121844E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.16979191E-06	0.32763000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.46294097E 04	0.46272978E 04	0.46240232E 04	0.46294697E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49730269E 04	0.49730269E 04	0.49730269E 04	0.49730269E 04	0.49730269E 04	0.49730269E 04
0.49730269E 04	0.49730269E 04	0.49730269E 04	0.49730269E 04	0.49730269E 04	0.49730269E 04
0.49730269E 04	0.49730269E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.68906602E 10	0.81445733E 09	0.33660808E 09	0.44281332E 05	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.29730757E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

ICOUNT =1162

X RHO	Y HSUM	S TT	P FETT	U	A
0.22079383E 01	0.00000000E-38	0.42493836E 00	0.15958696E 08	0.23792492E 06	0.41008450E 00
0.12114464E-02	0.69070461E 11	0.41734705E 04	0.18786483E 05		

XN(1) - XN(18)

0.26418936E-01	0.32473017E-02	0.10644142E-02	0.72101645E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.98505570E-05	0.69019380E 02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.72101644E-07	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.41865963E 04	0.41795997E 04	0.41758071E 04	0.41872427E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49561820E 04	0.49561820E 04	0.49561820E 04	0.49561820E 04	0.49561820E 04	0.49561820E 04
0.49561820E 04	0.49561820E 04	0.49561820E 04	0.49561820E 04	0.49561820E 04	0.49561820E 04
0.49561820E 04	0.49561820E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.59826895E 10	0.85112454E 09	0.26219495E 09	0.16280668E 05	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.28340596E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

STARTING CONDITIONS ICOUNT =1238

X RHO	Y HSUM	S TT	P EETT	U	A
0.27172925E 01	0.00000000E-38	0.93429248E 00	0.76339767E 07	0.26697866E 06	0.67928365E 00
0.65176310E-03	0.61737422E 11	0.37431883E 04	0.28439338E 04		

XN(1) - XN(18)

0.26486300E-01	0.36417400E-02	0.93586600E-03	0.33455000E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.38232000E-05	0.62416500E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.33455000E-07	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.37754268E 04	0.37519156E 04	0.37485502E 04	0.37783832E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49515225E 04	0.49515225E 04	0.49515225E 04	0.49515225E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.49515225E 04	0.49515225E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.49515225E 04	0.49515225E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.51449532E 10	0.82847326E 09	0.19856406E 09	0.64836363E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-39	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.28026745E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

ICOUNT =1268

X RHO	Y HSUM	S TT	P EETT	U	A
0.33031836E 01	0.00000000E-38	0.15201836E 01	0.43695400E 07	0.28737369E 06	0.98893340E 00
0.41591390E-03	0.56085643E 11	0.33740906E 04	0.45691642E 03		

XN(1) - XN(18)

0.26528460E-01	0.38624508E-02	0.85397861E-03	0.20030807E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.14910616E-05	0.58821325E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.20030807E-07	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.34464976E 04	0.33857429E 04	0.33857923E 04	0.34549660E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49504484E 04	0.49504484E 04	0.49504484E 04	0.49504484E 04	0.49504484E 04	0.49504484E 04
0.49504484E 04	0.49504484E 04	0.49504484E 04	0.49504484E 04	0.49504484E 04	0.49504484E 04
0.49504484E 04	0.49504484E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.44783148E 10	0.76494750E 09	0.15664869E 09	0.33813764E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.27981037E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

ICOUNT =1301

X RHO	Y HSUM	S TT	P EETT	U	A
0.47834566E 01	0.00000000E-38	0.30004566E 01	0.17255120E 07	0.31891761E 06	0.17712736E 01
0.20924415E-03	0.46523648E 11	0.26600775E 04	0.13498915E 02		

XN(1) - XN(18)

0.26560393E-01	0.40569546E-02	0.79153549E-03	0.11051651E-07	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.13916546E-06	0.55555762E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.11051651F-07	0.32263000E-03	0.00000000E-38	0.00000000F-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.29[illegible]8943E 04	0.26857129E 04	0.27136858E 04	0.29813686E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000F-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49499573E 04	0.49499573E 04	0.49499573E 04	0.49499573E 04	0.49499573E 04	0.49499573E 04
0.49499573E 04	0.49499573E 04	0.49499573E 04	0.49499573E 04	0.49499573E 04	0.49499573E 04
0.49499573E 04	0.49499573E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.34838906E 10	0.57805871E 09	0.10331271E 09	0.14688910E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.27973457E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

ICOUNT =1327

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.88093389E 01	0.00000000E-38	0.70263389E 01	0.21289408E 06	0.35686941E 06	0.73809476E 01
0.44874129E-04	0.33700059E 11	0.15331819E 04	0.15018847E 01		

XN(1) - XN(18)

0.26563820E-01	0.41285583E-02	0.78483803E-03	0.69403250E-08	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.20471279E-09	0.54190691E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.69403250E-08	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.27062275E 04	0.17756808E 04	0.20487333E 04	0.27638459E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49498691E 04	0.49498691E 04	0.49498691E 04	0.49498691E 04	0.49498691E 04	0.49498691E 04
0.49498691E 04	0.49498691E 04	0.49498691E 04	0.49498691E 04	0.49498691E 04	0.49498691E 04
0.49498691E 04	0.49498691E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.30058239E 10	0.30217733E 09	0.64042512E 08	0.81060892E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.27969656E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000F-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

ICOUNT =1336

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.11952980E 02	0.00000000E-38	0.10169980E 02	0.12269403E 06		
0.31366599E-04	0.30829247E 11	0.12642805E 04	0.14358948E 01	0.36482537E 06	0.10329160E 02

XN(1) - XN(18)

0.26563821E-01	0.41338116E-02	0.78483498E-03	0.61058253E-08	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.29405037E-10	0.54085656E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.61058253E-08	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.27016583E 04	0.16102102E 04	0.20002818E 04	0.27601143E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49498669E 04	0.49498669E 04	0.49498669E 04	0.49498669E 04	0.49498669E 04	0.49498669E 04
0.49498669E 04	0.49498669E 04	0.49498669E 04	0.49498669E 04	0.49498669E 04	0.49498669E 04
0.49498669E 04	0.49498669E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.29969402E 10	0.25342510E 09	0.61316040E 08	0.71146933E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.27969476E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

ICOUNT =1345

X RHO	Y HSUM	S TT	P EETT	U	A
0.17139134E 02	0.00000000E-38	0.15356134E 02	0.40009132E 05	0.37389538E 06	0.23122329E 02
0.13672118E-04	0.27479252E 11	0.94593007E 03	0.13998442E 01		

XN(1) - XN(18)

0.26553821E-01	0.41379439E-02	0.78483377E-03	0.53295278E-08	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.22843398E-10	0.54003021E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.53295277E-08	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26990794E 04	0.15166348E 04	0.19693548E 04	0.27580106E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49498655E 04	0.49498655E 04	0.49498655E 04	0.49498655E 04	0.49498655E 04	0.49498655E 04
0.49498655E 04	0.49498655E 04	0.49498655E 04	0.49498655E 04	0.49498655E 04	0.49498655E 04
0.49498655E 04	0.49498655E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.29919372E 10	0.22653856E 09	0.59585984E 08	0.62018996E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.27959359E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, continued

ICOUNT =1385

X / RHO	Y / HSUM	S / TT	P / EETT	U	A
0.41435554E 02	0.00000000E-38	0.39652554E 02	0.44254145E 04	0.38623199E 06	0.10574516E 03
0.28940682E-05	0.22790518E 11	0.49431526E 03	0.13354503E 01		

XN(I) - XN(18)

0.2 563821E-01	0.41399213E-02	0.78483252E-03	0.42130510E-08	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.27416850E-10	0.53963460E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.42130510E-08	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26987609E 04	0.15054654E 04	0.19660424E 04	0.27577144E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49498631E 04	0.49498631E 04	0.49498631E 04	0.49498631E 04	0.49498631E 04	0.49498631E 04
0.49498631E 04	0.49498631E 04	0.49498631E 04	0.49498631E 04	0.49498631E 04	0.49498631E 04
0.49498631E 04	0.49498631E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.29913186E 10	0.22344344E 09	0.59401094E 08	0.49017550E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.27969154E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-33

Hypersonic Nozzle Case, continued

ICOUNT =1407

X RHO	Y HSUM	S TT	P EFTT	U	A
0.12200000E 03	0.00000000E-38	0.12906595E 03	0.10858613E 04	0.39076016E 06	0.27966361E 03
0.10816113E-05	0.21031320E 11	0.32454008E 03	0.13944055E 01		

XN(1) - XN(18)

0.26563821E-01	0.41404643E-02	0.78483135E-03	0.31332021E-08	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.23540049E-10	0.53952603E-02	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.31332021E-08	0.32263000E-03	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TV(1) - TV(18)

0.26986850E 04	0.15091297E 04	0.19659581E 04	0.27576366E 04	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

TE(1) - TE(18)

0.49498618E 04	0.49498618E 04	0.49498618E 04	0.49498618E 04	0.49498618E 04	0.49498618E 04
0.49498618E 04	0.49498618E 04	0.49498618E 04	0.49498618E 04	0.49498618E 04	0.49498618E 04
0.49498618E 04	0.49498618E 04	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EV(1) - EV(18)

0.29911713E 10	0.22452286E 09	0.59396304E 08	0.36452053E 03	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

EE(1) - EE(18)

0.27969041E 06	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38
0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38	0.00000000E-38

Hypersonic Nozzle Case, concluded

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13. ABSTRACT

A computer program has been developed for one-dimensional nonequilibrium reacting gas flow. The program is written in Fortran IV and is compatible with the IBM 7044/7094 direct coupled digital computer system at Wright-Patterson Air Force Base, Ohio. In addition to nonequilibrium chemistry, the program includes nonequilibrium vibrational and electronic energy relaxation and coupling effects between these energy modes and the chemistry. The formulation is based on a one-dimensional flow matching either a prescribed pressure or area variation along a streamtube. Thermodynamic properties are computed by assuming an ideal gas mixture and the equilibration of translational and rotational temperatures. The internal energy modes, rotation, vibration, and electronic excitation, are considered uncoupled; and a rigid rotator, cut off simple harmonic oscillator, independent of the electronic state, is assumed. Excitation of vibrational and electronic energies are treated similarly with terms which account for relaxation and chemical reactions. The effects of nonequilibrium vibrational and electronic states on chemical rates are included in the coupling analysis. The vibrational relaxation time constants were obtained from the Millikan and White data while the electronic relaxation time constants were determined for nitrogen from an analysis of existing shock tube radiation measurements. The computer program was used to solve for the nonequilibrium flow in a hypersonic nozzle and for eight streamlines in the inviscid flow field over a spherically blunted nine-degree semiapex angle cone at zero angle of attack.

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